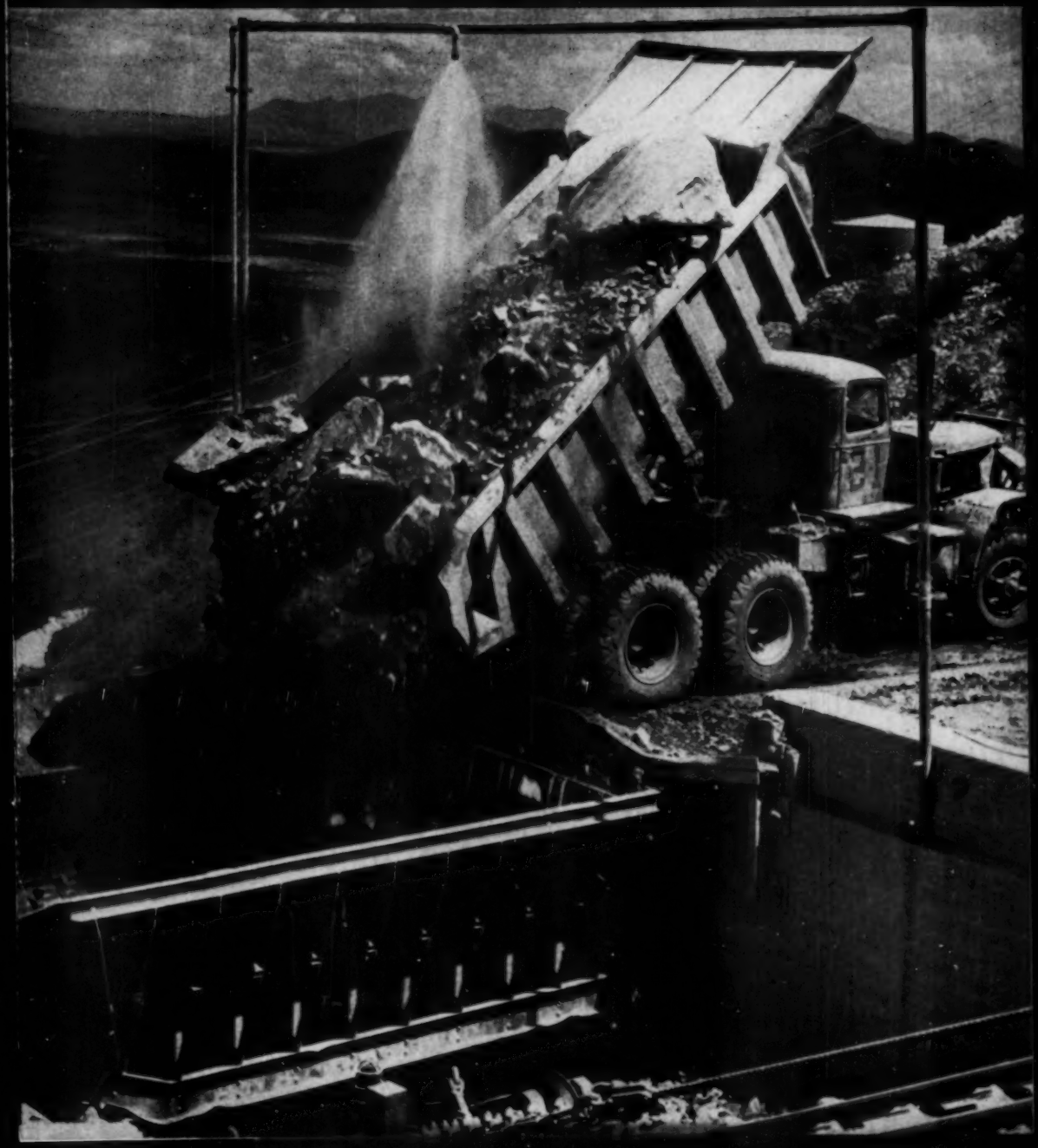
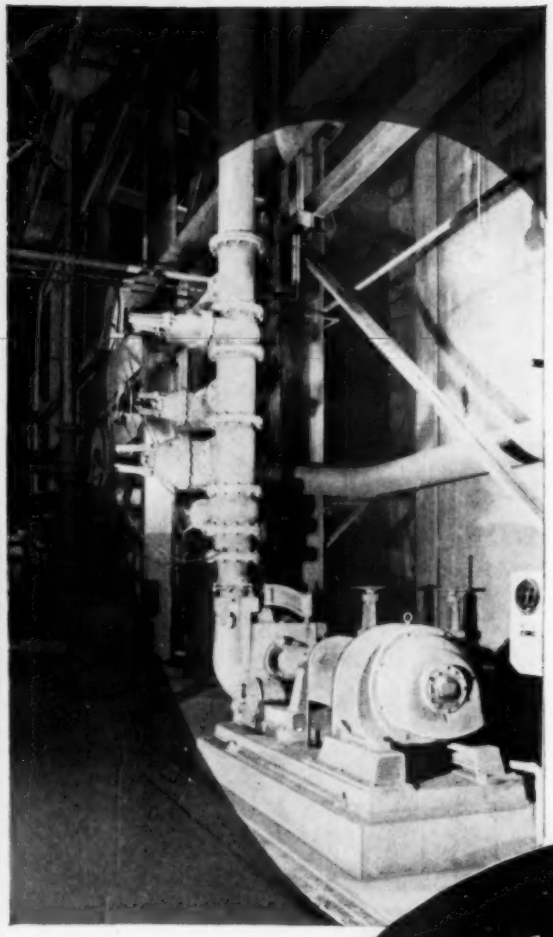
MINING ENGINEERING



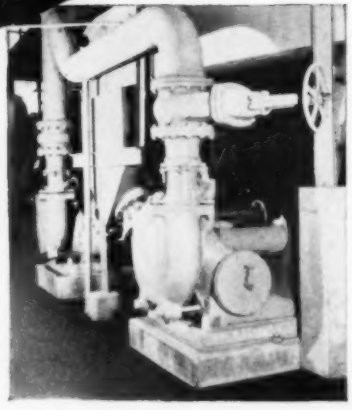


cement slurry

In every plant where slurries, sands or slimes must be handled on a cost-reducing basis, WILFLEY sand pumps can meet every requirement with a comfortable margin of reserve capacity. These famous pumps deliver continuous, trouble-free performance without attention ...stepped-up production...actual dollar-savings in power and operation. There is an economical WILFLEY pump size for every pumping problem. Individual engineering on every application. Write or wire for complete details.

Companion to the famous WILFLFY Acid Pump

WILFLEY
centrifugal **PUMPS**



At one of America's foremost cement plants, the 8 inch WILFLEY Slurry Pumps (illustrated) deliver cement slurry continuously at maximum pumpable density, with substantial power savings and minimum replacement of wear parts.

Buy Wilfley for Cost-Saving Performance

A. R. WILFLEY & SONS, Inc. Denver, Colo., U. S. A.
NEW YORK OFFICE: 1775 BROADWAY, NEW YORK CITY

MINING ENGINEERING

Incorporating Mining and Metallurgy, Mining Technology and Coal Technology

VOL. 187 NO. 5 MAY 1950

THOMAS E. LLOYD
Manager of Publications

• • •

JOHN V. BEALL
Editor

• • •

HAROLD N. UNDERHILL
R. L. GARRETT, D. G. GARRETT, M. BAGG,
Assistant Editors

WHEELER SPACKMAN
Advertising Manager

J. E. HALLORAN
Western Representative

GRACE PUGSLEY, *Production Manager;*
WALTER SEWING, *Assistant*

• • •

Technical Publications Committee

F. B. Foley ..... *Chairman*
E. J. Kennedy, Jr. ..... *Secretary*

• • •

Auxiliary Publications Committee Chairmen

R. D. Leisk ..... *Mining*
Richard H. Hunt ..... *Geology*
Leroy Scharon ..... *Geophysics*
M. D. Hassialis ..... *Beneficiation*
H. P. Greenwald ..... *Coal*
H. D. Keiser ..... *Industrial Minerals*
C. H. Behre, Jr. ..... *Education*
C. H. Behre, Jr. ..... *Mineral Economics*

• • •

The AIME publishes { **Mining Engineering**
Journal of Metals
Journal of Petroleum Technology

Published monthly by the American Institute of Mining and Metallurgical Engineers, Inc., 29 West 39th St., New York, 18, N. Y. Telephone: PEnnsylvania 6-9220. Subscription $8 per year for non-AIME members in the U. S., & North, South & Central America; $9 foreign; $6 for AIME members, or $4 in combination with a subscription to *Journal of Metals* or *Journal of Petroleum Technology*. Single copies $.75; special issues $1.50. The AIME is not responsible for any statement made or opinion expressed in its publication.

Copyright 1950 by the AIME.

Registered cable address, AIME, New York. Indexed in Engineering Index, Industrial Arts Index, and by The National Research Bureau. Entered as second-class matter Jan. 18, 1949, at the post office at N. Y., N. Y., under the act of March 3, 1879. Member, ABC.

FEATURES

Editorial 549
Reporter 547
It's Everyone's Business 550
Drift of Things 626
Authors in This Issue 544
Open-Pit Forum 564
Manufacturers News 546
AIME News 623
Coming Events 625

ARTICLES

The Outlook for Mining 552
Engineering Enrollment Drops 555
A New Approach to Taconite Utilization 560
Northern Appalachian Salt 557
Incentives for the Mining Industry 567
Oxidized Lead Ore Recovered Profitably 570

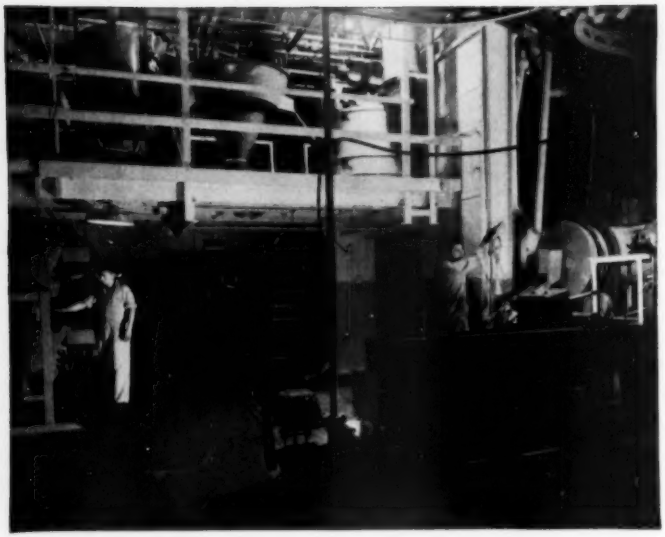
TRANSACTIONS

Classification and Application of Drill Jibs for Rock Drill Mounting 571
Production and Marketing of Garnet Abrasive Sands, Emerald Creek, Idaho 575
Nonmetalliferous Mineral Resources in Arkansas 577
The Burt Filter 585
Effect of Ba Cl_2 and other Activators on Soap Flotation of Quartz 591
Effects of Activators and Alizarin Dyes on Soap Flotation of Cassiterite and Fluorite 601
Laboratory Control in Coal Washing and Drying Plants 609
The Mechanism of Coarse Coal and Mineral Froth Flotations 616

Cover photo: Dumping a load of copper ore at the Greene Cananea Copper Co., Cananea, Sonora, Mexico. Picture by Frank Dey, smelter superintendent.

Personnel Service 542
Advertisers Index 638

New Process Yields 90% on Low-Grade Ore



PILOT PLANT GRINDING and concentration section of Basic Industries Laboratory shows closed circuit grinding, thickening, conditioning, and flotation facilities. This section of the pilot mill can handle 15-25 tons of ore per day.

How Allis-Chalmers Basic Industries Research Laboratory Helps Solve Problems for the Mineral Industries

A MINING company wanted an economical way to recover tungsten from low-grade scheelite ore. This called for a new process, involving crushing, grinding and concentration. The company brought this problem to the Basic Industries Research Laboratory.

Batch tests were made to determine possible processes that could be used. Tests were then run in the pilot mill to further refine the process and bring out hidden factors that might have been overlooked in batch testing.

The method finally arrived at — recovery of tungsten concentrate by a combination of flotation and gravity methods — was completely successful in pilot scale tests, resulting in a process yielding 90% recovery A-3003

THE ALLIS-CHALMERS Basic Industries Research Laboratory is primarily a service organization. It is manned by technically trained personnel and equipped with the necessary apparatus for investigating process problems that develop in the beneficiation of raw materials.

Will Mitchell, Jr. Director, Basic Industries Laboratory

Laboratory services include research on the development of new or existing industrial processes . . . research on new machinery, or improvement of old machinery . . . fundamental research into basic principles underlying modern mechanical, process or plant design.

The Laboratory's purpose is to develop new or more efficient methods... to determine the economics of processes prior to full scale production . . . to provide engineering information that will guide in the designing of efficient plants.

CAN YOU USE THIS SERVICE?

The services of the Laboratory are available to anyone in industry, regardless of the nature of their processes. All investigations are treated in complete confidence. Information obtained is not made public except with express permission of the sponsor.

The Laboratory is a service organization; charges are based on costs. An estimate for test work can be obtained through your nearest Allis-Chalmers district office, or by writing direct to:

ALLIS-CHALMERS, 971A SO. 70 ST. MILWAUKEE, WIS.

FROTH FLOTATION laboratory cell in concentration section of Basic Industries Laboratory is used for preliminary batch testing. PH meter in foreground provides close control of pulp acidity

ALLIS-CHALMERS

Basic Industries Research Laboratory — Dedicated to a Better Utilization of our Raw Materials

Look for the name AMSCO® on the dipper you specify...

Amsco Engineering — plus Amsco Manganese Steel Construction — means more efficient, more profitable shovel operation.

Profit is determined by *handling costs per yard*, and here are 2 important reasons why you can lower those handling costs with AMSCO Dippers:

Austenitic Manganese Steel—For Longer Life— The more you use an Amsco dipper, made of manganese steel throughout, the harder it gets! Surfaces that are subject to impact and abrasion actually work-harden and take on a high polish for added wear-resistance.

Manganese Steel—"the toughest steel known"—withstands the most severe breaking stresses.

AMSCO Engineering—For Better Operation— Years of Amsco design experience bring you a *complete line*, from which you can select dippers "custom-engineered" to your own requirements . . . for deep penetration, full loading and positive dumping. Whether you need manganese steel Welded, Missabe, Renewable Lip types, or special designs for unusual service, *you'll get longer wearing life and greater economy when you specify Amsco.*

NOW! Prompt delivery of Amsco Dippers and Parts

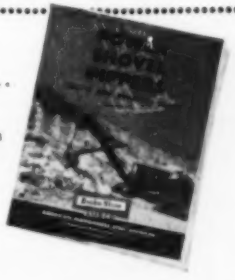
AMSCO
WELDING PRODUCTS

The fast, low-cost way to get worn or damaged equipment back in service.

Amsco hardfacing rods make important on-the-job savings . . . keep down time at a minimum. Contact your supply house or Amsco representative for information on the complete Amsco line of Welding Rod, Weldments and Repointer Bars.

Get the facts on the complete Amsco Line...

This 40-Page booklet is packed with information on Amsco Dippers, and parts for shovels and draglines. Write today for your free copy . . . ask for Bulletin No. 547 DS.



AMERICAN Brake Shoe COMPANY

AMERICAN MANGANESE STEEL DIVISION
417 EAST 14th STREET • CHICAGO HEIGHTS, ILL.

THIS NEW

DB-35 DRIFTER and 48" ALUMINUM SHELL

SAVES THREE WAYS!

1

28% LESS AIR
with the NEW DB-35 Drifter

Ingersoll-Rand's new DB-35 Drifter, with the patented double-kicker port valve, has been especially designed to increase operating economy. Tests prove that this new drifter actually requires 28% *less air* per foot of hole drilled! What's more, the new design has resulted in stronger rotation, better hole cleaning ability and improved feeding qualities. These combined features give you a rugged, heavy-duty drifter that will even surpass the record-breaking performance of Ingersoll-Rand's famous DA-35 Drifter.

2

33% FEWER STEEL CHANGES
with the NEW Lightweight 48-inch Aluminum Shell

The greater length of this new shell permits the use of longer drill steels—with 33⅓% fewer steel changes for a given footage. Its lightweight all-aluminum construction cuts shell weight almost in half! In fact, it's even lighter than the old-style 30-inch steel shell and has equal or better life. This light weight is particularly important when drilling from a column or bar.

3

50% MORE DRILLING SPEED
when Carset Jackbits are used

These longer-wearing, faster-drilling Carset Jackbits, tipped with tungsten carbide, enable you to take *full advantage* of the potential savings offered by the new I-R drifter combination. Often drilling speeds can be increased by 50% or more, tonnage can be boosted 20% or better and dynamite requirements can be cut as much as 30%. These savings, together with the many other proved advantages of I-R Carset Jackbits, set an all-time high in economy and performance.

THIS COMBINATION *is ideal for use with the famous I-R Drill Jumbo Mounting. For complete information check with your nearest Ingersoll-Rand office today. Let our engineers tell you more about this new cost-cutting combination.*

Ingersoll-Rand

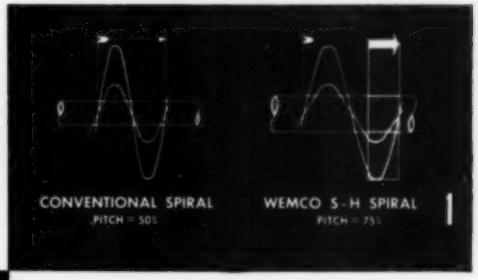
11 BROADWAY, NEW YORK 4, N. Y. 499-5

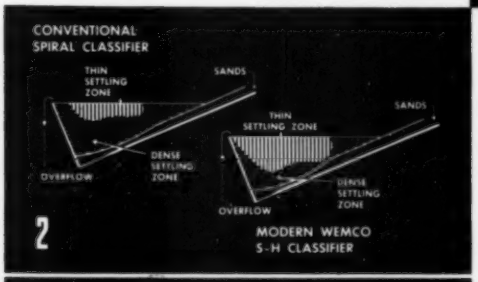
ROCK DRILLS • COMPRESSORS • AIR TOOLS • TURBO-BLOWERS
CONDENSERS • CENTRIFUGAL PUMPS • OIL & GAS ENGINES

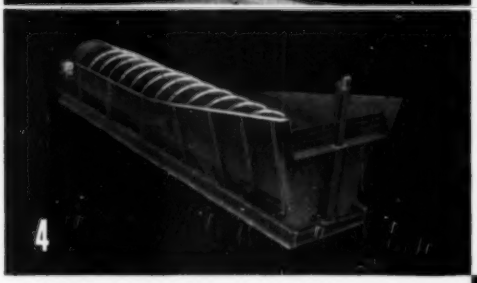
CARSET JACKBIT
SET WITH CARBOLOY INSERTS

The **WEMCO** S-H CLASSIFIER gives you

4 OUTSTANDING ADVANTAGES







1 GREATER CAPACITY

Up to 100% greater sand raking capacity, because the advanced pitch design provides for removal of greater quantities of settled sands, hence pool settling capacity is increased.

2 SHARPER SEPARATION

Sands are free of fines and overflow is free of sands, because greater raking capacity results in larger effective pool area. Since spiral speed is **not** increased, undesirable agitation of pool is prevented and maximum settling difference between fine and coarse particles is assured.

3 EASIER OPERATION

Simple hydraulic lifting device with remote control provides easy, foolproof operation, gives complete protection against clogging or jamming. Efficient drive and fully protected bearings are easy to maintain, assure dependable, continuous operation.

4 REDUCED OPERATING COSTS

Less shutdown time results because the sturdy tubular shaft is up to 50% larger than other machines of the same capacity; flight arms are correspondingly shorter and stronger. Since lineal length of spiral is 25% shorter, replacement costs of wearing shoes per ton of ore milled are 25% less.

Write today for descriptive Bulletin No. C-1-S-1.

WEMCO
WESTERN MACHINERY COMPANY
760-766 FOLSOM STREET · SAN FRANCISCO 7, CALIFORNIA

WKE (HMS) Mobil-Mill • Coal Spiral • Standard Thickeners (HMS) Thickeners • (HMS) Media Pumps • Hydroseparators (HMS) Densifiers • (HMS) Separatory Cones • "SH" Classifiers Sand Pumps • Conditioners and Agitators • Fagergren Flotation Machines • Dewatering Spirals • (HMS) Laboratory Units

PRINCIPAL OFFICES
San Francisco • Sacramento • Salt Lake City • Spokane
Pocatello, Idaho • Denver • Phoenix • Tucson • Chicago
Hibbing, Minnesota • Bartow, Florida • New York

EXPORT DISTRIBUTORS
The Ore and Chemical Co.
80 Broad Street • New York 4, N.Y.

Continental Europe and North Africa
Dr. Ing. Herbert Lickfett, A. B, Stockholm 3, Sweden
S. E. M. U. Paris, France
Ferdinand Egeberg & Company, Oslo, Norway
Midac, Milan, Italy
A. Schuberth & Company, Basle, Switzerland
G. Mattsimiotis & Co., Athens, Greece
Agence Miniere & Maritime, S. A., Antwerp, Belgium
Adil Gabay & Albert Koenka, Istanbul, Turkey
Philippine Industrial Equipment Co., Manila, Philippines
Fraser & Chalmers (S. A.) Ltd., Johannesburg, South Africa

Often worth its weight in Gold!

When production groans to a halt because of broken or fractured equipment, many shop-owners would gladly pay the price of gold for the few ounces of bronze needed for a reliable repair-weld.

They don't have to, of course. For repair-welding with Anaconda Bronze Rods—particularly Tobin Bronze*—is a low-cost, low-temperature method of oxyacetylene welding on cast or malleable iron, steel or copper alloys.

Over the decades that time-tried Tobin Bronze has served so well, many "new" rods and procedures have sprung up with mushroom-like growth, only to disappear as quickly—victims of their own lack of dependability!

Whether you do your own repair welding or call on outside help, play it safe—insist on genuine Tobin Bronze.

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut
Subsidiary of Anaconda Copper Mining Company
In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

*Reg. U. S. Pat. Off.

DON'T SCRAP IT . . . BRONZE WELD IT!

Bronze welding is safe, speedy and economical. Large or small, bronze welds are tough and readily machinable, high in strength and low in residual stresses—an ideal combination for repair welding, for building up worn surfaces, and for production welding, too. Tobin Bronze and other Anaconda Welding Rods are described in this NEW, 17th Edition of Publication B-13. Write for a copy.

ANACONDA
from mine to consumer

Anaconda
BRONZE WELDING RODS

Model 12B Eimco in mine in California

Model 12B in Lead mine in California

"...You can't beat an *EIMCO*"

To help you help yourself — Eimco offers three bulletins: on drawholes, L1017; on wide headings, L1018; and on tunnels, L1005A. They're available to bonafide mining men. Drop us a card today.

That's the way Eimco RockerShovel users talk —from the machine operators all the way up to Superintendents.

When you put a shovel underground, it's there to work for you. The men must use it—they must like it—it must be dependable! Eimco's alone meet these requirements. They stay underground longer—that's proven by their much lower maintenance costs. The men like them and use them because they're easier and safer to operate, stronger for lifting heavy muck, and faster in loading the cars. Yes, it's a fact established through performance in every mining camp throughout the world . . . You can't beat an Eimco; it is unquestionably the number one loading machine!

Write for more information — there's a RockerShovel to fit your loading needs.

EIMCO

THE EIMCO CORPORATION

The World's Largest Manufacturers of Underground Rock Loading Machines

EXECUTIVE OFFICES AND FACTORIES — SALT LAKE CITY 8, UTAH, U. S. A.

BRANCHES: NEW YORK CHICAGO BIRMINGHAM EL PASO BERKELEY DULUTH

AFFILIATED COMPANIES: SOCIETE EIMCO PARIS, FRANCE

EIMCO (GREAT BRITAIN) LTD. LEEDS 12, ENGLAND

AGENTS IN ALL PRINCIPAL CITIES THROUGHOUT THE WORLD

Model 21 in Copper mine in Arizona

Model 12B in Lead Silver mine in Utah

9832

Now... Available in Larger Sizes!

HYDROCONE* (Type R) CRUSHERS

***The term "Type R" by which these Allis-Chalmers crushers have been known has been changed to "*Hydrocone*." "Hydro" denotes the use of a static liquid, such as oil, used in the *Hydrocone* crusher for supporting and adjusting the height of the crushing cone. The principle of operation has not been changed.**

TO MEET new requirements for fine crushing in a larger range of capacities, Allis-Chalmers offers the expanded line of *Hydrocone* crushers, in sizes up to 1784 (17-in. receiving opening; 84-in. diameter cone) with coarse, intermediate or fine crushing chambers.

In the *Hydrocone* design the crusher's main shaft is raised or lowered hydraulically (push-button operation on the larger sizes) permitting quick, accurate product size adjustment without stopping the crusher. An Automatic Reset device lowers the entire crushing head hydraulically to pass uncrushable materials.

- Wobble plate feeder distributes feed evenly — standard equipment for crushers with fine crushing chambers.
- Spiral bevel gears, anti-friction bearings and improved clean oil lubrication. Smooth operation; long life!
- Simplicity of design reduces maintenance costs substantially.

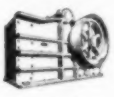
Get the complete facts about *Hydrocone* crushers — in sizes 122 to 1784 — from the Allis-Chalmers representative in your area. A-2933

IT PAYS TO SPECIFY MOTORS... CONTROLS... V-BELT DRIVES — ALL FROM ALLIS-CHALMERS

Motors — Controls

Texrope Drives

Vibrating Screens



Jaw Crushers

Kilns, Coolers, Dryers

Gyratory Crushers

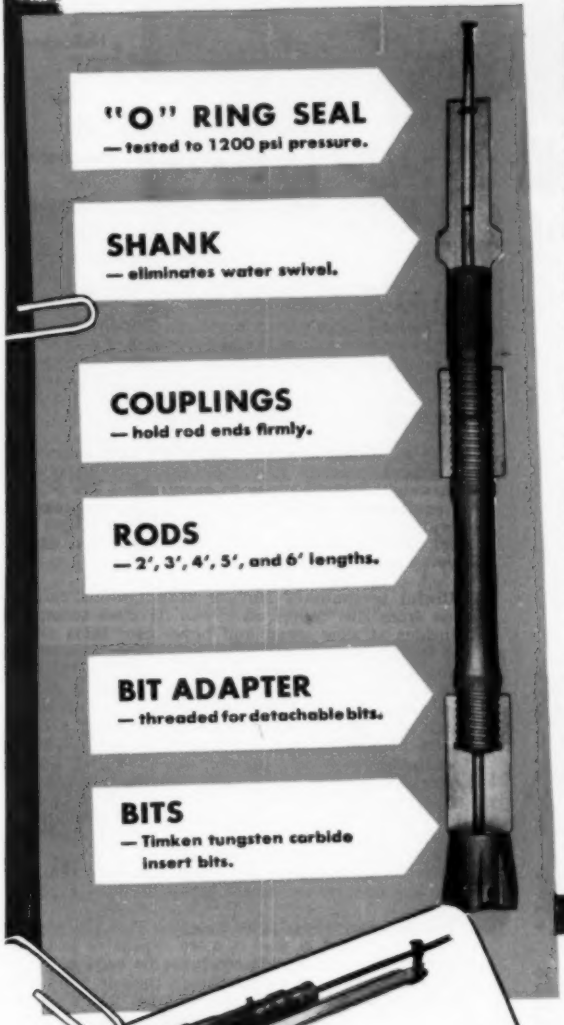
ALLIS-CHALMERS, 971A SO. 70 ST.
MILWAUKEE, WIS.

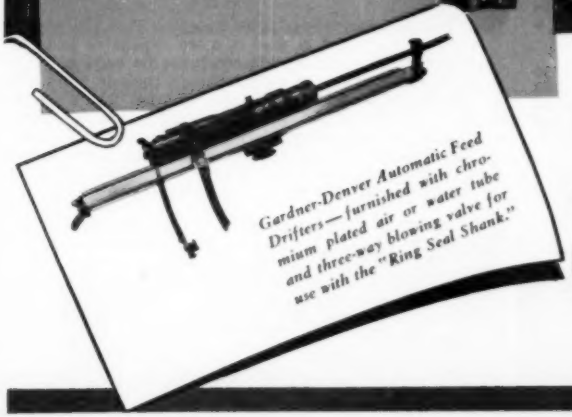
Texrope and *Hydrocone* are Allis-Chalmers trademarks.

ALLIS-CHALMERS

Sales offices in principal cities in the U. S. A. — Distributors throughout the world.

TODAY'S BIGGEST NEWS IN DEEP HOLE DRILLING




Gardner-Denver Automatic Feed Drifters—furnished with chromium plated air or water tube and three-way blowing valve for use with the "Ring Seal Shank."

GARDNER-DENVER DEEP HOLE DRILLING EQUIPMENT WITH "RING SEAL SHANK"

Here's a whole new set of field-proved drilling equipment that will revolutionize your deep hole drilling. Now, for the first time, you can take full advantage of tungsten carbide insert bits and modern rock drill power for faster, lower cost deep hole drilling.

No more water swivel troubles

The new Gardner-Denver "Ring Seal Shank" replaces the old type water swivel at a fraction of the cost—eliminates water swivel troubles.

Higher blowing pressures

"Ring Seal Shank" delivers water or air at any pressure that can be used on deep hole drilling—assures positive hole cleaning.

Longer rod and coupling life

Gardner-Denver sectional rods and couplings withstand the shock and grind of deep hole drilling—last much longer than conventional equipment — because they're manufactured with the same skill and precision as rock drill parts. Rod design has been carefully engineered to minimize stress concentrations and to form a tight union between all parts.

Tested and proved in the field

Gardner-Denver deep hole drilling equipment has been widely field tested—is now in use in many United States and Canadian mines—drills prospect holes at a fraction of the cost of diamond drilling.

Write today for complete information.

GARDNER-DENVER

Since 1859

Gardner-Denver Company, Quincy, Illinois.

In Canada:
Gardner-Denver Company (Canada) Ltd., Toronto, Ontario.

FOR SALE!

Endless Rope Haulage Hoist

at fraction of original cost

★

★ **MADE BY WELLMAN ENGINEERING Co.**

★ **CONDITION NEW**

★ **PACKED FOR EXPORT**

THIS Endless Rope Haulage Hoist was manufactured for a foreign government in 1945 and has been stored in its original export packing at a former U. S. Holding and Reconsignment Depot.

The haulages are designed for an effective haulage capacity or maximum working horizontal rope pull of 10,000 kilograms at a maximum rope speed of one (1) meter per second.

Drum diameter is 6' 6¾".

Rope: 1⅛" dia. 6 x 7 construction, hemp center, plow steel haulage rope, lubricated for overseas transportation, having a continuous - - one piece - - length of seven thousand and sixty (7060) lineal feet. Breaking strength of rope - - 127,000 lbs.

It is designed for operation on 380 volts, 3 phase, 50 cycle alternating current. Motor is Westinghouse, 200 h.p., 380 220 volts, 485 rpm, open, continuous 50 degree C rise, type CI, frame 32-C, wound rotor, ball bearing, with double straight shaft extension.

For complete specifications and details write, wire, or phone.

★

WEBSTER *Industries inc.*

Elmira Holding and Reconsignment Depot
Horseheads, New York

Letters to The Editor

Helicopter for Prospecting

DURING the course of recent prospecting for commercial minerals in Southern British Columbia, we have discovered that the helicopter is a very useful method of accelerating mineral exploration, assisting materially in the initial development of potential mines, and facilitating topographical and geological surveys.

The machines we used were Bell 47B3's stripped of everything possible and equipped with underslung lightweight freight racks to carry about 200 pounds of equipment and supplies. We made landings at elevations ranging from 5500 to 7600 ft above sea level, noting that an area of only 40 sq ft is necessary to accommodate a 'copter.

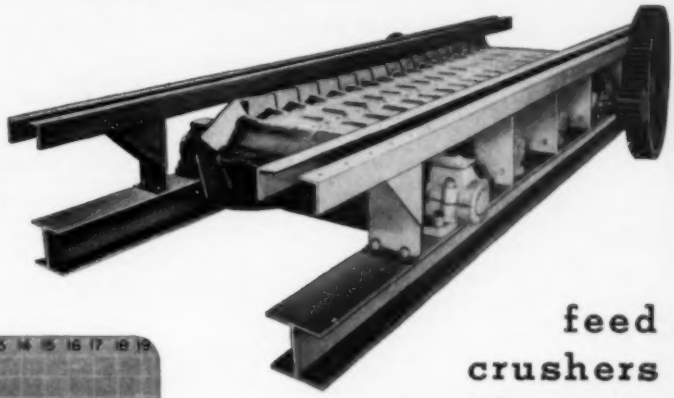
Useful preliminary surface examinations can be done from the 'copter, as it can fly close to mountainsides at slow speed and hover over talus slopes and stream beds. One of the greatest of 'copter advantages lies in the fact that it is available for continuous reconnaissance and for moving prospectors, thus avoiding tedious back-packing on foot. A small group of prospectors under the direction of a competent field engineer could cover effectively a large area in the course of a summer season. Flying a helicopter, however, is not a simple matter. It requires a pilot well experienced in mountain flying to cope with treacherous winds and up-and-downdrafts around ridges and peaks at high altitudes. However, we are convinced that the helicopter is a safe and ideal means of transport in mountainous country, when operated by competent personnel.

The helicopter is not the freighter that the Norseman or Fairchild is, and is more expensive to operate. Supplies and equipment must be kept down to minimum weight. Clothing should include wind and rain proof garments of the parka type. Tents should be of silk or nylon, and food supplies call for emphasis on the dehydrated type. The writers found that 2½ lbs of food per person per day were ample. A lightweight gasoline stove is a necessity for work above the timberline.

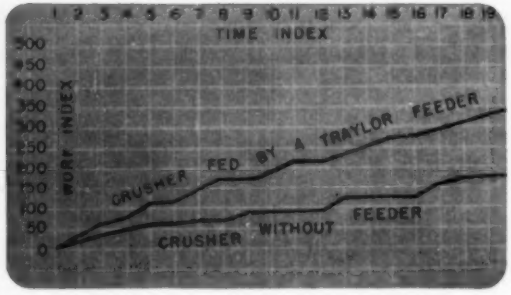
Although no mineral showings of commercial size and grade were found on our expedition, one unmapped area east of Gott Mountain disclosed interesting chalcopyrite and pyrrhotite mineralization, and a considerable zone of serpentine contacting the sediments to the north contained narrow stringers of asbestos.

G. T. Warren and W. J. MacKenzie
Kelowna, British Columbia

for MORE production with LESS attention...

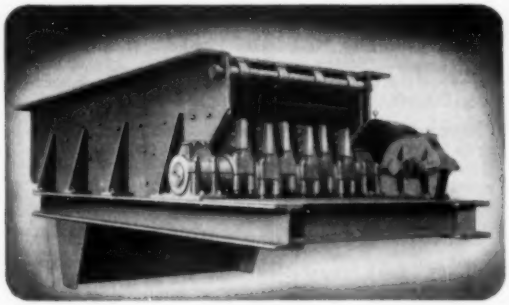


feed crushers evenly with TRAYLOR FEEDERS



This chart clearly shows that a crusher evenly fed by a Traylor Feeder consistently produces more than twice as much as that same crusher without a feeder. That's because there are no peaks and valleys in the material supply.

Generally, any jaw or gyratory crusher is most efficient when working with a controlled feed of material. This is especially true in primary operations. Traylor all-steel Apron Feeders will increase crusher production by supplying a steady even flow of material at all times. Overlapping, heavy steel aprons and flanges maintain a solid surface . . . prevent material leakage. Widths from 30" to 84" in any practical length desired.



Traylor Grizzley Feeders have massive reciprocating bars of steel topped with renewable wear plates. These plates are suitably slotted to remove undersizes before they reach the crusher . . . all of the crusher production is used to reduce oversize. In sizes from 3' x 6' to 10' x 20'

FREE NEW FEEDER BOOKLET

Traylor builds a complete line of feeders for many purposes. Increase your profits by operating your crushers at their most efficient capacity. Write today for illustrated Bulletin 1114 which describes Traylor Feeders in detail.

TRAYLOR ENGINEERING & MANUFACTURING CO.
342 Mill St., Allentown, Pa.

Sales Offices: New York, N. Y., Chicago, Ill., Los Angeles, Calif.
Canadian Mfrs: Canadian Vickers, Ltd., Montreal, P. Q.

Traylor

Rotary Kilns, Coolers and Dryers
Grinding Mills · Crushing Rolls
Jaw, Reduction and Gyratory Crushers

A "TRAYLOR" LEADS TO GREATER PROFITS

Engineering Societies Personnel Service

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service, Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18**; 100 Farnsworth Ave., **Detroit**; 57 Post St., **San Francisco**; 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6¢ in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter or $12 a year.

Allen Joins Personnel Service

Bonnell H. Allen has been appointed assistant to the manager of the Chicago office of the Engineering Societies Personnel Service, Inc. Mr. Allen, a licensed engineer, has had a background of a number of years in engineering personnel placement work.

Positions Open

Safety Engineer, under 40, with experience in safety work at mines, and experience in underground mines. Must be able to speak Spanish fluently. Must go single status for six months. Salary, $3600-$5328 a year, plus traveling expenses. Location, Cuba. Y3094.

Mining Engineer familiar with foreign ores and minerals, for export-import house. Location, New York, N. Y. Y3106.

Mining Consultant for central staff position, with at least ten years' experience in management and direction of strip coal mining. Should have ability to purchase, plan, direct maintenance, etc., for nineteen mines. Salary, $15,000-$20,000 a year. Headquarters, New York, N. Y. Y3117.

Manganese Mining Engineer. Must have at least five years' specialized experience in strip manganese mining, and a very complete knowledge of all equipment used in this operation. Location, Arkansas. Y3118.

Mining Engineer, under 35, with field experience in non-metallics, and a statistical turn of mind for staff position with mining company. Salary open. Location, New Jersey. Y3215.

Engineers for newly developed copper property. (a) Concentrator Superintendent for 1500 ton per day differential flotation plant. (b) Smelter Superintendent for wet charged reverberatory, waste heat boiler, rotary converters, 35/40 ton refining furnace, casting machine, etc. Pulverized coal fire. (c) Concentrator Shift Foremen. (d) Smelter Shift Foremen for all departments. (e) Chief Assayer-Chemist. Minimum two year contracts. Location, northeastern Turkey. Y3257.

Mine Engineer, young, graduate, with two to three years' experience in surveying, sampling, etc. Salary, $3300 a year, plus room and board. Standard two year contract. Should speak Spanish. Location, Central America. Y3447.

Men Available

Manager or Superintendent of Mines, 49, married. Twenty years superintendent, manager and professional engineering of mines with reductions of ores by amalgamation, flotation and cyanide. This experience has been in open pit, underground and placer mines and all types of mechanical equipment. Available short notice. Prefer U.S. or Central America. M-527-503-E-5-San Francisco.

Mine Superintendent-General Foreman, 46; married, no children. Operated both capacities States, Mexico, Central and South America. Engineering background, fluent Spanish. Labor relations experience. Excellent record Latin American labor. Can produce tonnage and lower mining costs. M-528-503-E-1-San Francisco.

Mining Executive, 53, married, E.M. (Geology) degree in 1919. Excellent references. Ten years' experience mining geologist, foreign and domestic. Twenty years' experience various supervisory positions large mining company in South America. Location immaterial. M-530-503-E-6-San Francisco.

Mining Engineer, 38, married, no children, Malayan tin 3 years; Butte copper 4 years; England explosive research 4 years; Canadian gold 8 years. Speak Spanish, seek exploration and development management in Americas or West Indies. M-531.

Mining Engineer, 29, married, B.S. Mining Engineering. Five years' engineering and operating experience. Excellent record and references. Desires responsible position with progressive company. Available 30 days. M-537.

Graduate Mining Engineer, 35 years' experience all phases of mine development, operation, planning, milling, desires position in charge or as assistant. Location immaterial. M-538.

Mining Engineer, 29, single, E.M. degree 1947, Colorado School of Mines. Two years mine surveying and drafting. Location preferred, U.S.A. M-539.

Mining Engineer, many years' experience various metal mines, exploration, operation, development, including tin, placer and lode gold. Experience in many countries organizing, financing, etc. Married, no children. Available immediately. M-516.

Minerals Engineer - Metallurgist - Microscopist, 29, B.S. (Metallurgy) Montana School of Mines; M.S. (Mineral Dressing) M.I.T. Three years' minerals processing research and development; two years' practical mining; additional business training and supervisory experience. Desires position as assistant to executive or responsible position plant or laboratory. M-517.

Mill Superintendent, graduate, 41, married, no children. Wide experience on mill operation, construction and maintenance. Capable, progressive, cost conscious, good record handling men. Fluent Spanish. Available short notice. M-518.

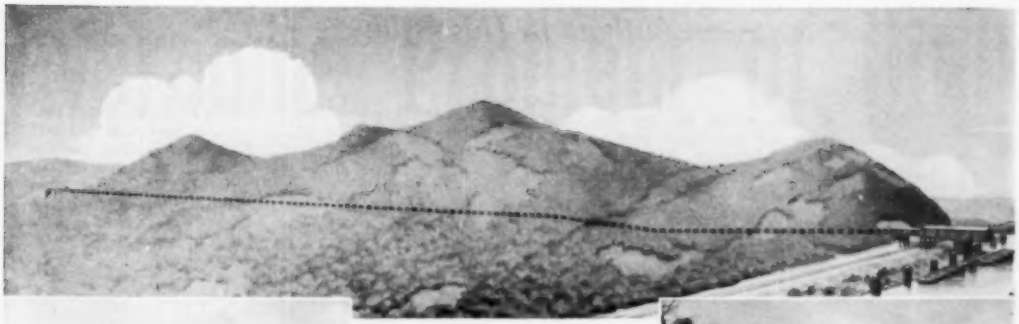
Coal Preparation Expert Wanted

The Military Government of Japan urgently needs an expert in the coal field to advise on preparation,—principally washing and dressing. Salary: $7,600 per year. Free housing, low cost of living. Minimum term of service: two years. Dependents cannot accompany the person selected, but may follow at a later date. Concurrent travel of a wife only is permitted.

Write to: Department of Army, Office of the Sec'y, Overseas Affairs Branch, CPD, 139 Centre St., 6th floor, New York 13, N. Y.

WANTED IMMEDIATELY—Assistant mill superintendent for large tin operation Bolivia. Spanish and Latin American background essential. Standard three-year contract with transportation, housing provided. Salary $5000 or more, depending on experience.

Box E-11—MINING ENGINEERING



TWO MILES IN ONE FLIGHT!

Here coal is prepared in this new blending and washing plant completely designed and built by Link-Belt. From this plant the washed coal is delivered to the tunnel belt conveyor (right side of above photograph) on which it is transported to the river and rail loading station.

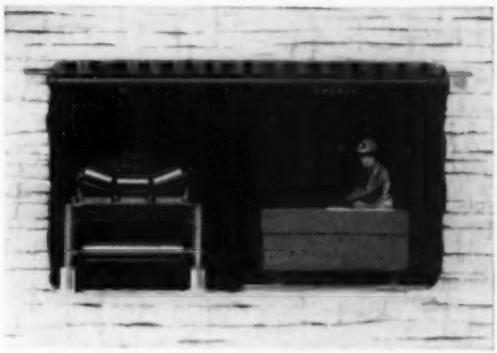
River and rail loading station also built by Link-Belt Company where washed coal is loaded into barges, or by means of a by-pass conveyor, into railroad cars.

World's Longest Single Belt Conveyor

Through a mountain, under forests, roads and streams this single 30" wide belt conveyor transports coal from preparation plant to river and rail loading station—10,900 ft. from foot pulley to head pulley—more than four miles of belt operated by one drive!

After careful analysis of various methods of transportation ultimate economy dictated the selection of this belt conveyor. By building this conveyor in one flight, intermediate transfers, heavy machinery and power wiring were eliminated from the tunnel.

Link-Belt Company engineered, equipped and erected the blending and washing plants, the conveyor equipment and the river and rail loading station. Resulting success of this and other similar projects illustrates the importance of such coordinated effort.



Typical cross-section through tunnel showing belt conveyor and battery driven patrol car. Standard Link-Belt type "100" idlers are used throughout the 2-mile long belt conveyor.

LINK-BELT COMPANY

Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8, Johannesburg. Offices in Principal Cities. 11,044-A

LINK-BELT

Belt Conveyor

EQUIPMENT

IDLERS • TRIPPERS • BELTS
PULLEYS • BEARINGS • DRIVES

—— Authors in This Issue ——

R. Schumann

R. Schumann, Jr. (p. 601) has been an associate professor in the metallurgy department at MIT for the past five years, and also works for the Atomic Energy Commission's famed Manhattan Project. Born in Corpus Christi, Texas, he attended Long Beach Polytechnic High School in California, and then went to the California Institute of Technology, Missouri School of Mines, Montana School of Mines, and MIT, taking B.S., M.S., and Sc. D. degrees. An AIME member, he has presented several papers in the field of mineral dressing.

W. B. Mather

W. B. Mather (p. 577), economic geologist with the Midwest Research Institute in Kansas City, has had a long and varied career, working in the fields of economic geology, industrial minerals, petrography, and geochemistry, to name a few. He has been chief field assistant for the Ontario Geological Survey, principal geologist for the Missouri Geological Survey, and has done extensive consulting work in petrography and industrial minerals. He served for three years as an aeronautical engineer with the Royal Canadian Air Force. During the last five years he has presented six papers before the Institute on the mineral deposits of Oklahoma and Arkansas. Born in Weston, Ontario, he attended high school there and has since taken B.A., M.A., and PhD. degrees, at McMaster Univ., at the Univ. of Toronto, and at the Univ. of Chicago.

W. G. Woolf

W. G. Woolf (p. 585), superintendent of the Sullivan Mining Co.'s electrolytic zinc plant at Kellogg, Idaho, has been working at refining and research since he took his M.S. in metallurgy from the Univ. of Utah in 1914. After working as a metallurgist for four western companies, including Bunker Hill & Sullivan, and doing research for the USBM at the Univ. of Utah, he joined the Sullivan Mining Co., taking charge of the zinc plant there. He initiated research on the "complex ores" of the Coeur d'Alene district for Bunker Hill, which research culminated in the zinc plant of the Sullivan Mining Co.

H. L. Lines, blasting and drilling foreman for Phelps Dodge at Morenci, Ariz., has been engaged in various types of mining work for 27 years. For seven years he was in underground mining, then followed four years of leasing, and a year in vanadium mining and milling. He has been with Phelps Dodge since 1942.

R. A. Mullins took his B.S. in chemical engineering from Rose Polytechnic institute, Terre Haute, Indiana, and, working for Ayrshire Collieries Corp. since 1941, was made chief chemist in January of last year. Mr. Mullins spent four war years with the USAF in Europe and Africa. Born in Seelyville, Indiana, he attended Glenn High School in Terre Haute, now lives in Oakwood, Illinois.

R. W. Jenkins was born in Fargo, N. D., attended Bismarck High School in that state, and took his B.S. from the Univ. of North Dakota. He has been a junior engineer for the London Mines and Milling Co., Alma, Colo., a miner for Mountain City Copper Co. in Nevada, and, starting as a sampler, worked up to shift boss at Butte for Anaconda. He is now a special representative for the Joy Mfg. Co. in Pittsburgh. Mr. Jenkins is an AIME member.

A. Y. Bethune

A. Y. Bethune (p. 585) leads a busy life out in Kellogg, Idaho, where he takes a lively interest in both his professional work (as assistant superintendent of the Sullivan Mining Co.), and in many community activities. Born in San Francisco, he attended Mission High School there, and then went on to the Mackay School of mines at the Univ. of Nevada, to take a B.S. in mining engineering and the professional degree of metallurgical engineer. Twenty-two years ago he started out as an assayer in the Sullivan Mining Co.'s electrolytic zinc plant, advanced through the experimental and research laboratory to become plant metallurgist in 1942, and assistant superintendent in 1946. He has been an AIME member since 1936, and presented his first TP just ten years ago. Mr. Bethune devotes much time to community problems, church work, the Kellogg YMCA, and still finds time for some golf.

James Boyd

James Boyd, director of the U. S. Bureau of Mines, was born at Kanowna, West Australia. He took his B.S. in engineering and economics from the California Institute of Technology in 1927, and went to work as a field engineer in Los Angeles immediately after graduation. In 1929 he entered the Colorado School of Mines, and a year later he became an instructor there, studying simultaneously. His studies led to the acquisition of an M.S. in 1932 and a D.Sc. two years later. Dr. Boyd later became dean of the Colorado School, and in 1947 he was appointed director of the USBM.

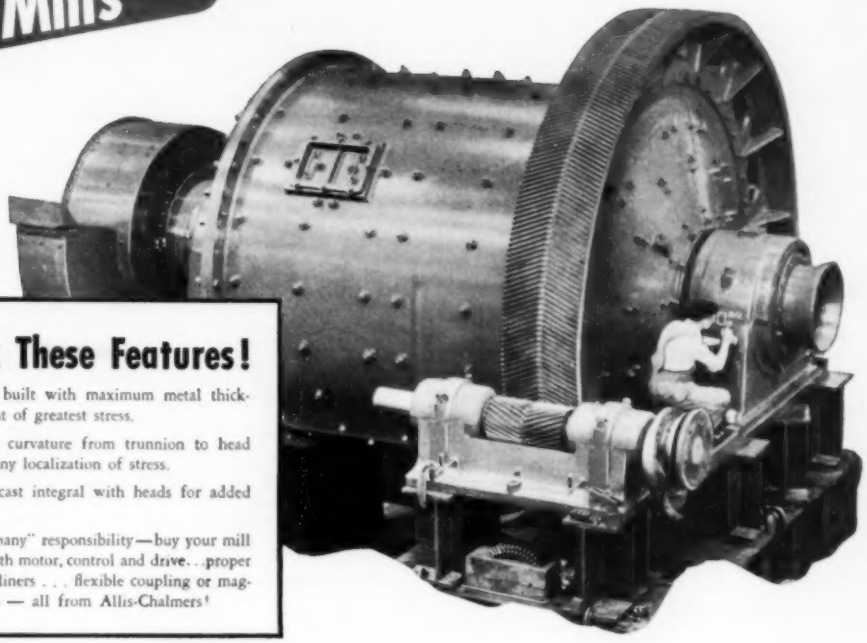
E. V. Given

E. V. Given has been, since 1945, mill superintendent for the St. Anthony Mining and Development Co., Ltd., Tiger, Ariz. Born in Gillette, Wyoming, he attended high school there. Mr. Given has been mill superintendent for Coronado Copper & Zinc in Dragoon, Ariz., U. S. Smelting's Artimesa Unit in Mexico, and for the Etna Gold Mines, Modena, Utah. Mr. Given is an AIME member.

Lawrence Ormsby has been at Morenci for eleven years, and is now mine superintendent there. He has served as a junior engineer for the Braden Copper Co. in Chile, and as an engineer for the National Park Service. Born in Casper, Wyoming, he attended Shattuck Military School in Faribault, Minn., and took his B.S. from the Univ. of Wyoming.

Overcome Problem of High Starting Torque

ALLIS-CHALMERS Grinding Mills



Check These Features!

- Trunnions built with maximum metal thickness at point of greatest stress.
- A gradual curvature from trunnion to head eliminates any localization of stress.
- Trunnion cast integral with heads for added strength.
- "One company" responsibility—buy your mill complete with motor, control and drive...proper feeder and liners . . . flexible coupling or magnetic clutch — all from Allis-Chalmers!

TRUNNION BEARINGS on all the larger sizes of Allis-Chalmers grinding mills are supplied with an individual high pressure lubricating pump to provide lubricant between mill trunnion and bearing during initial starting, insuring minimum starting torque and bearing wear.

Hand operated bearing lubricating pump.

Floating the mill in this way results in much less punishment to vital parts. Reduced starting torque gives you less strain on gear teeth and less torsional strain on the pinionshaft.

REDUCES DOWNTIME

Protection from excessive wear and strain in starting your mill will prove to be immensely important in terms of less costly maintenance and less idle mill time. Another reason it pays to specify A-C mills!

Allis-Chalmers builds a complete line of grinding mills: ball and rod mills; pebble mills, Compeb and Ballpeb mills. The A-C representative in your area can be a big help in working out grinding problems. Call him today, or write: A-5044

ALLIS-CHALMERS, 971A SO. 70 ST. MILWAUKEE, WIS.

Compeb Ballpeb and *Texrope* are Allis-Chalmers trademarks.

ALLIS-CHALMERS

Sales Offices in Principal Cities in the U. S. A. Distributors Throughout the World.

Motors

Controls

Texrope Drives

Vibrating Screens

Crushers

Kilns, Coolers, Dryers

Manufacturers News

The Goodman Mfg. Co., Chicago, builders of underground electric mining machinery, celebrated its 50th Anniversary on April 23rd. The company has a complete line of cutting machines, loaders, conveyors, locomotives, and shuttle cars for service in both coal and metal mines.

The Joy Mfg. Co. has received, under the provisions of the Economic Cooperation Administration, an initial order in excess of $1,000,000 for equipment to be used in the mechanization of iron ore mines in France. While the equipment will be used in various privately owned mines, the order was placed through the French Society for the Development of Mechanical Mining. Included in the equipment are the company's recently developed hard rock loaders and shuttle cars.

American Brake Shoe Co. has consolidated all operations of its Canadian subsidiaries into one corporation, the Dominion Brake Shoe Co. Ltd., Montreal, Canada. The products of Dominion Brake Shoe include brake shoes, track equipment, manganese steel castings, automotive brake lining, air compressors, and paint spray equipment.

Exhibits of more than 2000 electrical products, processes, and techniques, ranging from precise aircraft instruments to complex working models of steel mill, textile and other industry equipment, will be displayed in the "More Power To America Special" when it makes its nationwide tour this spring. C. H. Lang, Vice-President in charge of sales for **General Electric's** apparatus department, said that the train will visit the country's key industrial centers for inspection by utility and industrial executives and municipal leaders. The train will be hauled by an Alco-G-E two-unit, 4000-hp., Diesel-electric locomotive which in itself will be part of the unusual series of displays.

Sizing of Excavators and Hauling Equipment. The Power Crane and Shovel Association has released a 24-page bulletin dealing with the proper sizing of excavators and hauling equipment, Technical Bulletin No. 3.

Rubber Conveyor Belting. "Installation, Care and Maintenance of Rubber Conveyor Belting" is the title of a booklet just published by the Carlyle Rubber Co., New York.

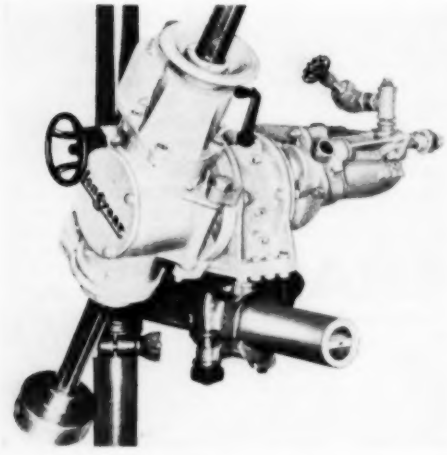
Power Transformers. The manufacturing procedure of Allis-Chalmers small power transformers is described in a new 28-page bulletin, 61B6094A, covering the core and coil unit, no-load tap changer, tank construction, cooling methods, oil preserving systems, bushings, terminal compartments, indicators and testing of transformers.

Safety Equipment. General Scientific Equipment Co., Philadelphia, has released a 46-page, fully illustrated catalog on personal protective equipment and industrial safety devices. This new catalog covers respiratory devices, eye protection, hats, gloves, carboy pumps, drum pumps, and miscellaneous safety equipment for use in mines, industries, etc.

Osmosalts. The Osmose Wood Preserving Co., Buffalo, N. Y., has issued a bulletin on Osmosalts, the wood preservative which, say the manufacturers, makes timber last three to five times longer, slashes maintenace costs, stops rot, and resists wood-destroying insects.

Jigs. The Dorr Co. has acquired the Pan American jigs and they are now known as the Dorrco-Pan American jigs. Originally developed as a gold-saving device for dredges, the simplicity, ease of operation, efficiency, and negligible maintenance of these jigs have resulted in wide adoption on all types of placer operations, in the closed grinding circuits of gold mills, and on many applications where a coarse bed concentrate is separated from the ore gangue.

Hi-Speed Prospector Core Drill



Pictured (left) is the Longyear Hi-Speed Prospector core drill, featuring the 2-speed transmission which permits the operator to shift into low gear when drilling broken or hard formation, and at the same time employ the full power of the duplex air motor. With the ordinary drill, slowing the speed for tough drilling is accomplished by throttling the air motor, which in turn reduces power when most needed. This model is adapted for underground use in testing mineral values, and securing core data as a guide in development work. Blastholes are rapidly drilled at low cost. The Hi-Speed Prospector is useful also in drilling holes for ventilation or drainage, electric cables, and for grouting purposes. It weighs 275 pounds complete, is easily handled by two men. The drill can be broken down into three units, the heaviest of which is 152 pounds. It can be mounted on a mine column, cross-bar or side arm. Capacity is 500' of $1\frac{1}{2}$-in. hole, core $\frac{7}{8}$ in. in dia., or 400' of $1\frac{7}{8}$ in. hole, core $1\frac{1}{8}$ in. in dia. The duplex air motor develops 9 hp and the duplex principle reduces the danger of "freezing." The swivel or drilling head may be rotated for drilling holes at any angle. Feed gear selections to suit particular needs are available. This core drill, manufactured by the E. J. Longyear Co., Minneapolis, is described in their Bulletin No. 80.

WICKWIRE ROPE

A PRODUCT OF CF&I

Ask any user . . . you'll find them everywhere

In scores of industries, users of Wickwire Rope have developed an affectionate respect for its performance, safety and long life. And, for true economy, they use Wickwire's WISSCOLAY® *Preformed*. It lasts longer—is easier to cut, splice and install. It's kink-resistant and safer to handle. Wickwire Distributors and Rope Engineers, in key cities everywhere, are prepared to render prompt service in meeting your wire rope needs. Wickwire Rope Sales Office and Plant—Palmer, Mass.

IN THE EAST—Wickwire Spencer Steel Div. of C. F. & I.
500 Fifth Ave., New York 18, N. Y.
IN THE ROCKIES—The Colorado Fuel and Iron Corp.
Continental Oil Bldg., Denver, Colo.
ON THE WEST COAST—The California Wire Cloth Corp.
1060—7th Ave., Oakland 6, Cal.

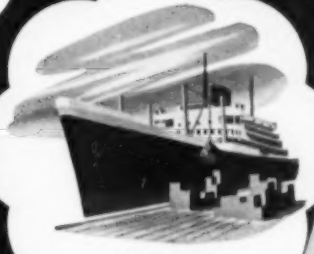
LOGGING

TRANSPORTATION

MINING

PETROLEUM

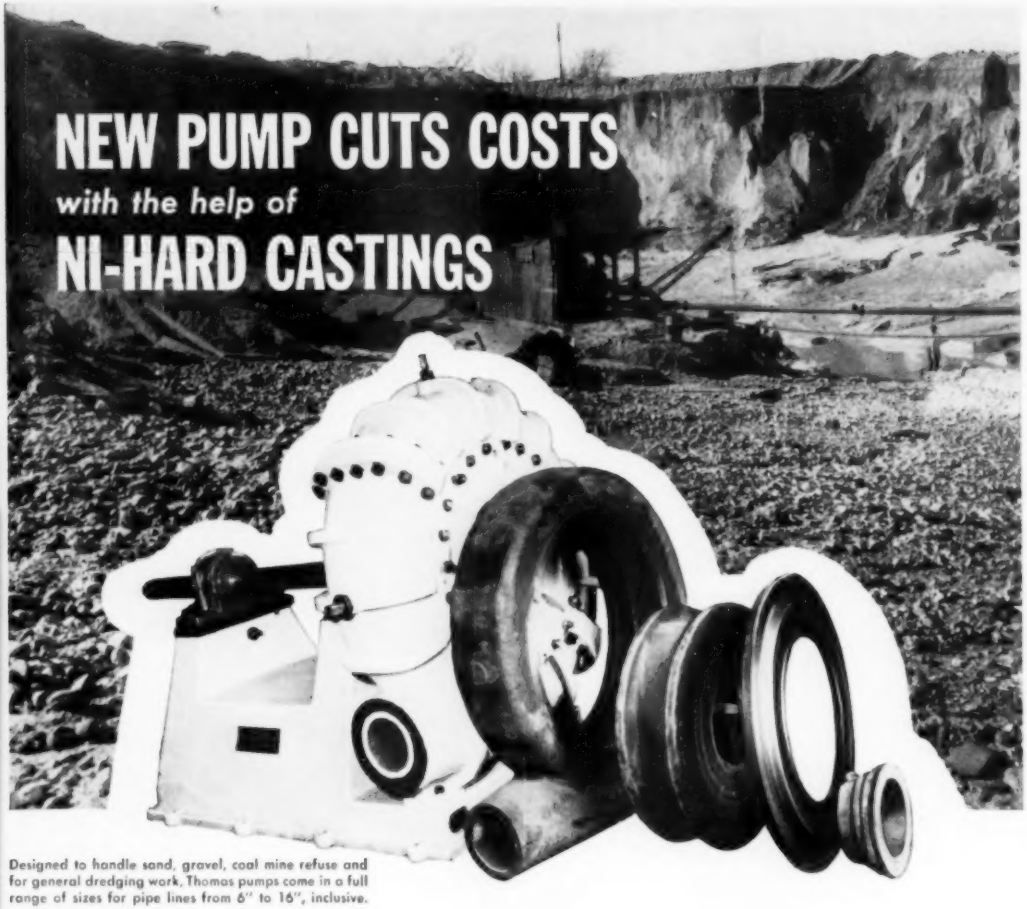
MANUFACTURING



MARINE

CONSTRUCTION

NEW PUMP CUTS COSTS
with the help of
NI-HARD CASTINGS



Designed to handle sand, gravel, coal mine refuse and for general dredging work, Thomas pumps come in a full range of sizes for pipe lines from 6" to 16", inclusive.

Here's a solids-handling pump that answers one of the toughest problems in the mining industry...

This new type of pump was developed and built by Thomas Foundries, Inc., of Birmingham, Alabama, to take full advantage of Ni-Hard®... *the hardest commercially available product of the cast iron industry.*

For the ultimate in service life, a water jacket provided between shell liner and outer casing reinforces the liner and allows it to be worn almost paper-thin without breakage. Moreover, the confined water transmits impacts from heavy rock and hydraulic rams or blowbacks to the strong outer casing.

SINCE SEPTEMBER 1948, a Thomas Durable Dredge Pump has been operating in a plant where no other pump ever remained more than 3 to 4 weeks without requiring major repairs. The unit has cut maintenance labor to a fraction of former needs and eliminated use of a booster pump. Although under a total head of 140 feet, this Thomas pump (10" suction, 8" discharge) powered by a 200 horsepower Diesel engine, moves 2700 gallons per minute and handles from 150 to 175 tons of sand and gravel (up to 6") per hour.

Impellers, shell liners, suction side liners, engine side liners, throat and seal rings are cast by Thomas Foundries in Ni-Hard having a minimum Brinell hardness of 550.

For superior and more economical service, specify Ni-Hard for your equipment parts subject to wear and abrasion.

The International Nickel Company, Inc.
Dept. ME, 67 Wall St., New York 5, N. Y.

EMBLEM OF SERVICE INCO

Please send me free booklets entitled:
"ENGINEERING PROPERTIES AND APPLICATIONS OF NI-HARD" and "BUYERS GUIDE FOR NI-HARD CASTINGS"

Name.....Title.....

Company.....

Address.....

City.....State.....

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N.Y.

* A complete magnetic picture of the Mesabi range is now available for the first time with the release of 21 additional maps based on the aeromagnetic survey of 30,000 square miles made jointly by the USGS and the Minnesota Geological Survey.

A potential iron formation with a magnetic pattern remarkably like that of the Mesabi iron range lies buried beneath the glacial drift in a wide belt extending some 30 miles across the northwest corner of Itasca County in north central Minnesota.

* Identification of three new uranium minerals by the USGS was recently announced. The new minerals, andersonite, swartzite, and bayleyite are, respectively, hydrous uranyl carbonates of magnesium, of sodium and calcium, and of calcium and magnesium. They were first observed by Charles A. Anderson, Survey geologist, in a coating on gypsum on the 300-ft level of the Hillside mine, Yavapai County, Arizona.

* International Minerals and Chemical Corp. has announced a $4,000,000 expansion and development program in the Polk County phosphate fields in Florida. Plants for the manufacture of multiple superphosphate and phosphate chemicals including dicalcium p osphate for animal feed and chemical purposes, and a sulphuric acid are planned. Office building, machine shop, warehouse, and laboratory are also scheduled for erection.

* A new type of tramp iron detector is being used on the conveyor belt feeder at the South Agnew stripping operation. It is made of an alloy of aluminum, nickel and cobalt and does not have any electric coils. The alloy, known as Alnico, is remarkable for the permanence and intensity of the magnetism which it retains. The detector was made by Dings Magnetic Separator Co. and it is probable that Alnico will be used in magnetic separators.

* The American Society of Engineering Education estimates that unless the percentage of high school graduates entering engineering colleges is increased, there is a strong possibility that instead of a large surplus of engineering graduates, which has been propehsied rather widely, there will soon be fewer engineering graduates available than are needed annually by our national economy.

This conclusion is reached from a survey that shows that engineering enrollments are only slightly higher than prewar whereas industrial expansion is increasing the need for engineers.

* The natural resources of Korea are being investigated under ECA sponsorship. E.J. Longyear has just embarked 8 crews for that country; two drills are scheduled for base metal search while six are slated for development of coal reserves.

* An innovation in the development work in the iron country has been the adoption of the Drill-Mobile, jumbo-mounted drills on rubber-tired carriage, by Cleveland-Cliffs at the Mather A and B mines. The machine is being used to cut stations in the new Mathed B shaft and for driving development headings at the Mather A.

Step Up Recoveries

WITH THESE TWO FLOTATION "FIRSTS"

Yarmor® F Pine Oil

Hercules "Yarmor" F Pine Oil has been a standard of quality among pine oils ever since the flotation process became established. Low in cost, it is recognized as the ideal frother for the flotation of sulphide minerals, such as zinc, copper, lead . . . and for non-sulphide minerals, such as mica, quartz, graphite, feldspar, and talc. A relatively new and profitable use is in the salvaging of coal fines for fuel. Here, as wherever a highly mineralized froth is required to support and hold heavy concentrations, "Yarmor" F Pine Oil assures maximum recovery.

Rosin Amine D Acetate

Rosin Amine D Acetate is a new type of collector developed by Hercules for the flotation process. This cationic surface-active material is low in price, has good solubility, and is easy to handle. Rosin Amine D Acetate is employed in the flotation of non-metallic ores, such as feldspar, cement rock, and phosphate rock. It is an excellent collector for silica and siliceous minerals and may have application in the removal of these substances from other ores. Hercules Rosin Amine D Acetate is shipped to flotation users in the form of a water-soluble, 70 per cent paste.

Send for new technical book on Hercules flotation agents

HERCULES POWDER COMPANY

INCORPORATED

955 KING STREET WILMINGTON 99, DELAWARE

NM50-2

The Age of Specialization

TIME was when the mining engineer was all things to the exploitation of mineral resources. He was educated in geology so that he could undertake exploration; he was versed in the methods of mining and related engineering problems; he knew the techniques of concentration and the metallurgy of extracting the metal from the concentrate. As the technology of mineral exploration has evolved, the mining schools have instituted specialized training courses to equip engineers to cope with the more elaborate technologies characterized by each of the above phases of mineral recovery.

The trend of increased specialization has been evident in fields other than mining; medicine, law and physics, among others, have each broken down into numerous specialty fields. Advances have paralleled the growth of specialization which has, in fact, made them possible. Clarence Day recognized this trend in the 1920's when he was writing his book "This Simian World." He noted that such a high degree of concentration of one's efforts was required for an individual to make an original contribution to science, that he must perforce sacrifice being abreast of the everyday subjects necessary for the "informed person."

Clarence Day has put his finger on the nub of the problem. To become specialists, must we bury our heads so deep in our own studies that we miss the social and economic implications of our work, and, equally important, must we become social outcasts because we are not up on the latest McCarthy disclosure or the baseball scores? We think that the answer to this question is no. Being posted on what is going on in related fields of science will be of advantage to us in our work. We must also assume that we will be required to solve social and economic problems imposed on society by technologic progress.

The truth of this statement is vividly portrayed by the predicament in which the world is today because nuclear physicists have developed atomic energy to a point where society is not equipped to handle it.

Some individuals in the mining industry have not been slow to recognize the dangers of overspecialization. William B. Plank, in an article in the March *Mining Engineering* deplored the degree of diversification in mineral industry curricula. Arthur F. Taggart, in the April issue, presented a new type of engineering education which would give the undergraduate a broad training in basic engineering fundamentals. The required degree of specialization for effective work in a field may be gained on the job or in graduate training. However, the engineer must continue his education in the broader aspects of the profession on his own after graduation. This job is made relatively easy for him by his professional society and the numerous technical and nontechnical periodicals.

In the Mining Branch of AIME we find evidence of the fundamental unity of the mining profession. Although divisionalized by specialties, we have the same problems in economics and labor relations. With increased mechanization in the mines, methods and equipment are becoming interchangeable among metal, coal, and nonmetallic operations in many cases. The AIME meetings and publications have become a common meeting ground for the exchange of ideas between the divisions of the profession.

Although this is the so called "age of specialization," the alert engineer keeps his associations broad and his reading diversified lest overspecialization be his undoing.

It's Everyone's Business

APRIL 10—Officially, spring comes to the Great Lakes on March 21 as it does elsewhere in the country but in the Superior district continued snow and freezing until late in March have caused citizens in Duluth to place their bets on April 15 for the first ore vessels if the ice break-up is left to Mother Nature.

North and west of Duluth and near the eastern end of the Mesabi lies the little town of Aurora, population 1100. As the little v-nosed snowplow, pride of the community, shuttled back and forth clearing Aurora's few sidewalks, the crowd in Bradich's Cafe were more interested in the impending high school state championship basketball tournament in Minneapolis than in the outcome of Erie Mining Company's petition for water rights for their proposed 10 million-ton taconite concentrating plant. Such a plant would employ 4500 workmen, and at the prevailing ratio of 10 people for every mine worker in Minnesota, this would mean a 45,000 increase in population for Aurora and the vicinity in the next few years.

Downstate fishermen are alarmed at the flurry of activity by the mining companies in pushing plans for large scale recovery of iron from taconite. Inconvenience to these gentlemen will be inconsequential when compared with the vast increase in payrolls for range communities. Oliver is pushing the construction of a fine ore agglomeration plant at Virginia which will give them valuable experience for projected taconite processing. Oglebay, Norton & Co. is ready to go at Beaver Bay, north of Duluth, as the right of way for a railroad from Babitt to Beaver Bay is secured as well as permission to dispose of tailing into Lake Superior at the site of the proposed concentrating plant. This company is also doing research in agglomeration at Ashland, Ky., in cooperation with other interests. The financing is yet to be worked out.

Of the four possibilities for agglomerating taconite concentrate—sintering, pellitizing, nodulizing and briquetting—the prospects for pelletizing appear the most favorable. It seems likely that 60 cents per ton can be saved by this process over sintering because only 1 to 2 pct of coal is required as compared with 7 pct for sintering. One reason for the lower coal consumption is that the chemical transition of magnetite to hematite which transpires in the pelletizing process is exothermic.

Foreign policy has become a matter of partisan politics in recent months partly because of Senator McCarthy's attack on the State Department, the loss of China to the Communists, and the illness of Senator Vandenberg, chief architect of bipartisan foreign policy. Steps have been taken for a reaffirmation of bipartisanship by the appointment of two Republicans, John Foster Dulles, a former Senator, and John Sherman Cooper, former Senator from Kentucky, as "consultants" to Secretary of State Dean Acheson. Meanwhile, Senator Vandenberg saved his party's blushes by neither condemning it for obstructing the European recovery program nor rolling the State Department in the mud. He simply wrote a letter to another Republican, Paul G. Hoffman, ECA head, in which he reminds his colleagues that they are engaged in a struggle that is epochal in nature and of global design. He pleaded for a return to unity and suggested that since American commitments extend beyond the election year 1952, a nonpartisan commission composed of the country's ablest men should consider the best way of meeting them.

There are strong political pressures that could conceivably block this effort. For instance, Senator Robert A. Taft has a different definition of bipartisanship than that of the Administration. He thinks that Republicans in Congress should

be consulted rather than the Administration's hand-picked "consultants". It is true, however, that Vandenberg recommended the selection of Dulles as a "consultant" to Secretary Acheson.

It is to be hoped that unity will prevail as the problems to be faced are sufficiently knotty to require the best heads in our government, be they Democrat or Republican. In the Far East the further spread of Communism must be stopped, and in Western Europe the dollar gap must be closed. These will be difficult feats after the Marshall Plan ends in 1952.

Senator Vandenberg's letter to Mr. Hoffman was taken in certain foreign quarters to be an admission that American economic aid would continue beyond 1952. Considering that the best estimates made by OEEC indicate a deficit of $1 billion for Western Europe and its dependent territories in the first year beyond 1952, this is

not surprising. Besides offsetting this dollar gap by increased importation of foreign commodities, it will be necessary to encourage the investment of American private capital abroad. Exploitation of foreign sources by American oil companies are a classic example of this type of investment. The London Economist suggests that if President Truman's Point IV program is to overcome the dollar gap by mobilization of American capital for this type of investment, private savings and subscriptions to public issues by the private investor through an investment corporation in which the transfer risks are guaranteed by the U. S. Government will have to be made.

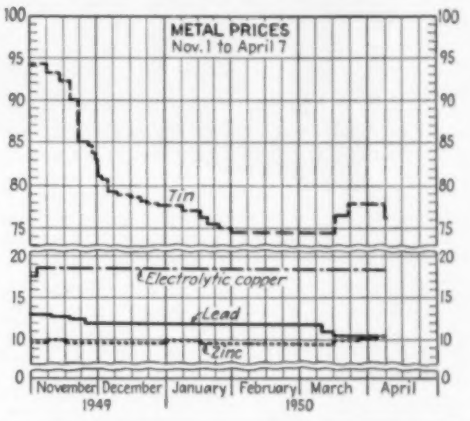
ECA negotiated $54,745,580 in purchases for the U. S. stockpile in the first two years of its operation. The purchases were made by utilizing the U. S. portion of counterpart funds deposited by European countries to match aid furnished under the Marshall Plan. ECA contracts for purchasing for the stockpile have enabled certain foreign mining ventures to come into or expand production. Besides supplying our stockpile, they have made additional sources of supply for metal consuming industries here.

Although the stockpile represents military security to a degree, foreign sources of supply would be tenuous in the event of war. American strategic mineral development, excepting uranium, has been allowed to lag for the lack of government support. J. Carson Adkerson, of the American Manganese Producers Association, urged approval of a bill authorizing the Government to underwrite domestic production of low-grade manganese ores. Such a program would require government price support and long term contracts. Although the Bureau of Mines and the USGS have done considerable work in finding and estimating the grade of many strategic mineral deposits, they cannot be brought into production rapidly enough to meet wartime contingencies.

Rising living costs have taken away the share of goods to which old-age pensioners and other fixed-income persons are entitled. For many in this group the decline in interest rates on bonds and mortgages, together with higher prices, have created a double squeeze on real purchasing power. The accompanying chart shows the relationship between average hourly earnings, productivity in terms of output per manhour, and prices of manufactured goods. A striking example of the reason for the rising cost of living is shown by the increase of average hourly earnings in recent years without a corresponding increase in output per manhour. Although these figures are approximate, the decade between 1939 and 1949 saw a 120 pct increase in average hourly earnings while manhour output has probably gained but 15 pct. Prices have therefore been forced up almost 90 pct. The average hourly earning figure does not include labor costs for vacations, sickness, pensions, etc. The productivity figures are rough because of changing composition and quality of products made, and for this reason no figures are given for the war period.

The other major influence in the declining purchasing power of the dollar is the great increase in government expenditures and the method of financing them. In the 1920's all levels of government absorbed 8 pct of the available resources of men and materials but this figure has risen to over 18 pct today. Thus the government, by preempting its share of the resources in a period of already heavy demand, drives prices higher. The way to halt the spiral of increasing prices is to hold wage increases to a more reasonable relationship with productivity and to reduce the draft on resources absorbed by big government.

Discussion of unemployment in Congressional committees has been largely theoretical and statistical; but with one out of every thirteen workers looking for a job, unemployment figures are beginning to make news. Although 58.5 million people are now drawing wages or salaries, nearly 4.7 million people were unemployed in the week ending February 11, and the number who had



been without work for 15 weeks or more rose by 160,000 between January and February, to a total of 1.1 million. The average length of time an unemployed person had been seeking work increased from eleven to twelve weeks. President Truman called for 61 million civilian jobs in 1950 and national income of $300 billion a year by 1955, all of which may make it rather difficult for the country to act like a creditor nation as efforts are intensified in this direction toward the latter part of the year.

The position in which British Overseas Airways Corp. has been placed by the late delivery of 14 Boeing stratocruisers points out the proximity of commercial gas turbine aircraft. BOAC ordered the aircraft for delivery in December, 1947 but the first did not arrive until October 15, 1949, and the last one was delivered the first week of April. Since the operating life of an aircraft is eight years, these planes should be run until 1958, but the turbo-prop Bristol 175 being developed by the Bristol Aeroplane Co. may possibly be ready in four years. Since gas turbine aircraft have lower running costs and added passenger comfort because of silent, vibrationless operation, it is questionable if the piston engine stratocruiser could compete on the same routes. BOAC is not the only airline faced with this problem of obsolescence of equipment before the expiration of its working life.

The Outlook for Mining

by James Boyd

IT is obvious that mining has been influenced to a high degree by political and economic events, many of which are of such a nature that the mining industry has relatively little influence in shaping them.

I cannot present too optimistic a picture for the immediate future, although I feel that from the long-range standpoint one need not be pessimistic about the future of the mining industry. The population of the United States is continuing to increase and with it has come an expanded consumption of metals on a per capita basis. With this expansion there has and will continue to come the demand for more goods and increased products from our mines and our fabricating plants.

World War II disrupted our national economy to a far greater extent than did World War I. Despite this disruption less time was lost reconverting to normal operation than in the period after 1918. In most industries reconversion has not presented too serious a problem. However, the time has now come when the backlog of consumer demands for raw materials have been virtually satisfied. The violent fluctuations of metal prices during the past 15 months has reflected this and full adjustment has not yet been realized. Metal requirements could not possibly remain at war and postwar peaks. Obviously there has to be a period of retrenchment.

I appreciate that it is not very consoling for those who are mining nonferrous ores to realize that in the long run the future may be bright but meanwhile they may go out of business. Unfortunately some operators in the high cost category may be unable to escape the pressure of economic events.

The postwar stockpiling program has unfortunately added to the uncertainties of the industry; international affairs forced accelerated action before the backlog of civilian demand was satisfied, and budgetary limitations forced curtailment in mineral and metal procurement for the stockpile at about the time consumers' inventories had reached a saturation point. It is well to remember that stockpile procurement must come from productive capacity in excess of current industrial requirements; consequently the termination of stockpile acquisition is bound to leave idle productive capacity, unless it can be timed to bridge the gap between past peaks and growing commercial demand. It is unlikely that such a favorable coincidence will occur. Consequently I feel that the mining industry must be prepared for a period of retrenchment when stockpiling ceases. Already the program for stockpile procurement of some materials has terminated—at least for the present.

It might be proposed that stockpiling be continued in such a fashion as to cushion the shock of sudden cessation. Unfortunately this is a difficult thing to do. Stockpile procurement does not have for its primary objective the stimulating of the mining industry. Parenthetically the stockpile must provide an ample available supply of strategic materials for national emergency, and it should be obvious to all of you that an effective stockpile must be well balanced at all times: it is undesirable for there to be an excess supply of one metal to the detriment of another.

Mr. Boyd is director of the U. S. Bureau of Mines and an AIME member. This is a condensation of a paper presented before the American Zinc Institute in St. Louis, Mo., April 11, 1950.

THE termination of stockpile procurement will create problems for the industry, but the author calls for preparation now for a strong future. Needed:—more public and Government support for exploration and technological improvements.

National security as afforded by stockpiles is not a matter that can be reduced to a secondary position.

On the other hand, an active and producing domestic mineral industry is a source of national strength and has been so recognized by the stockpiling authorities. I firmly agree with this concept.

It seems to me that there is a sound argument in favor of a national program that would work rapidly toward stockpile objectives while recognizing the lethal effect on the domestic industry of a sudden and possible unpredictable termination. In a few cases where such a condition has arisen through changing requirements, the need for such a program has been recognized—at least by those of us in Government who are familiar with the problems of the mining industry. Adjustments have been made where possible within available authority. Unfortunately when stockpile objectives have been attained, it has been impossible to prevent the closing of certain domestic mining operations—quicksilver and antimony are cases in point.

It has been stated repeatedly that the mining industry is a sick industry. Such a statement requires analysis. For most mineral products industrial demand is as great today as it was before the war and from all indications this trend is likely to continue; in most cases, all requirements, including stockpile accumulation within the budgetary limits, are being met. Metal prices for the most part compare with prices of other commodities but unfortunately there has been no thorough study of the relationship between metal prices and increased over-all mining costs.

It has been claimed by many who have been studying the problems of the mining industry that in the nonferrous portion of the industry at least, the price of the product is not keeping pace with increasing costs of metal production and increasing cost of exploration. If this claim is correct, this is not a favorable situation. We are currently engaged in analyzing the cost problem and if our studies substantiate this conclusion, it is my hope that within the next few months the Bureau of Mines may be able to secure sufficient data to present an authoritative report on the status of the nonferrous metals industry to the public. In this report recommendations would be made with the hope of correcting present conditions.

The economic and technologic problems of the mining industry are not fully appreciated, either by the Government or the public; the industry has never had a good press in terms of public relations. Let us compare mining with manufacturing: the manufacturing industry, with which the public is more familiar, has a relatively easier problem with respect to flexibility. Adjustments from peak war demands for given products to normal peacetime requirements for a different product are made quickly and production capacity can be adjusted to accommodate orders from customers. In the mining industry, however, reduced demand forces the elimination of the higher cost units. Furthermore, operations which have been laboriously undertaken under the spur of wartime necessity, and which may have become depleted as a result of this emergency production, are faced with financial disaster. The public has never appreciated those hazards of the metal mining industry.

The only legislative solution so far proposed to the problems facing the higher cost units of the industry now threatened with liquidation is by Government aid through various forms of subsidy. The 81st Congress has made it clear that it is in no mood for such action at this time.

It is unnecessary for me to review the reasons for the National program with respect to ECA and the Marshall Plan. The people of the United States through Congress have endorsed our assistance to foreign nations in order to build up a bulwark against Communist inroads throughout Europe. As long as we hear "thunder on the left" there is no doubt in my mind but that this program will be supported by the majority of the American public. The domestic mining industry may suffer severely as a result of the cold war. We might just as well face these facts.

The American people have chosen: they were faced with two alternatives, the first the alternative of constrictive nationalism which would have

meant the building up of a large military machine and preparation for out and out war; the second that of attempting to bolster the failing economies of European nations on the theory that it would be cheaper to do this than it would be for us to attempt the maintenance of a tremendous military establishment in times of peace. Whether or not the choice of the American people was a wise one will have to await the verdict of history.

Is there any silver lining to the cloud which at the present moment is enveloping the nonferrous mining industry? As I have stated earlier, I think that we would be wrong to be overly pessimistic. We must assume that through our help, and their own efforts, the European economy will grow; I am convinced that the time will come when metals produced abroad will be consumed largely by the countries involved. I appreciate the fact that this may take several years but undoubtedly that time will come. It will mean the loss of certain foreign markets to us, but on the other hand it should react to our domestic advantage in that there would be less foreign metal and mineral available for marketing within the United States. Increased demand for our industrial products should increase the domestic demand for minerals. Furthermore, as I have stated previously, our own population is growing and this means increased demand for the products of our mines.

With respect to zinc, is it possible for us to make any predictions? There have been technological developments in the metallurgy of zinc which promise to have important effects on the industry. Beginning about 1940 there was a marked rise in the use of special and regular High Grade zinc because of a sudden increase in the use of zinc die casting alloys. This trend toward the increased use of the higher grades is likely to continue. This, in the case of galvanizing, may be at the expense of the Prime Western grade. Patent rights for galvanized sheet production, in connection with which High Grade zinc has sometimes been used, have recently been licensed to the Inland Steel Company.

Recent developments by the Bell Telephone Company of transistors as a substitute for electronic rectifiers and amplifiers has resulted in the rise in importance of germanium, an important by-product from zinc processing. Germanium, as some of you know, is one of the best electronic-valve materials which is the essential element for transistors. As a result of this development it is very possible that there will be an increased demand for germanium in the foreseeable future. Until recently germanium was being extracted only by the Eagle-Picher Company, but now other zinc producers are becoming more interested. At the present moment the price of elemental germanium is about $300 per pound.

There has been an increase in recovery of zinc from lead blast furnace slags by zinc fuming. This has made it feasible to recover zinc associated with lead ores and concentrates that previously was lost in the blast furnace process and also makes it possible to utilize lead-zinc ores and other complex ores that are difficult to separate into lead and zinc concentrates.

The trend toward greater use of vertical retorts and mechanical charging and discharging will undoubtedly have an important influence upon the industry, and an influence for the good. Aside from the elimination of occupational hazards, these changes have been prompted largely by the increased cost of labor. It is reasonable to anticipate that further reductions in cost will occur as these techniques are developed.

Since lead has an important bearing on zinc production, it is unfortunately necessary to add another word of warning. Industrial stocks have been rising, foreign markets are weak, and stockpile accumulations are rapidly reaching their goals. The price has already dropped and a curtailment of production may be necessary in the near future. Lead, because of high stockpile purchases, has been slower to go through the serious adjustments that are necessary to achieve market stability.

As long as domestic industrial production continues to expand I think there is no doubt that there will be increased need for metals. If we compare a critical index, and I think you will agree with me that automobile and truck production would be an excellent criterion for this purpose, we find that in 1941 the United States produced on an average of 98,236 trucks and automobiles per week. Today our average weekly production is over 127,000. If we take another production index which is convenient for our use, Business Week states the electric power output in million kilowatt hours averaged somewhat in excess of 3,000 for the year 1941. A month ago the average was nearly double that of 1941. I think that you will agree with me that these figures indicate that the country is not retrenching —that industry itself is expanding and it must be evident that in order for it to function effectively under such conditions of expansion, metals will be needed.

In order that the industry remain strong it is vitally necessary that during this period of transition it turn its attention to preparing for the future. It has become obvious to all but the blind that our reserves have not been developed at the desired rate. The door is virtually closed for price support and production subsidies. The need for encouraging exploration must become more fully recognized. If the point is made clear to the Government and the public, and not clouded by extraneous issues and the problems of individual operators, there is some hope for constructive action. This includes not only support of exploration for new and extended deposits, but also for technological improvements so that today's marginal ores will become the reserves of tomorrow.

Engineering Enrollment Drops

. . . but Mineral Engineering Enrollment is Maintained

by W. B. Plank

THE figures on enrollment in the engineering schools of the United States and Canada indicate that the total number of students in these schools for the current year, 1949-50, is about 10% less than it was a year ago. This year, 226,533 undergraduates and graduate students are studying engineering in the United States and Canada as compared with 249,913 students last year. These figures are taken from advance data in the Journal of Engineering Education for February 1950.

Professor Plank is an AIME member, and heads the department of mining and metallurgical engineering at Lafayette College, Easton, Pa. This paper was presented before the Mineral Engineering Education Division, AIME, at Columbia Univ., Feb. 13, 1950.

Although the enrollment in the other engineering branches is approaching the predicted postwar figures, the mineral engineering group as a whole is about the same size as it was in 1948-49. A total of 11,283 students are enrolled in the mineral engineering schools of the United States, which is about the same number as last year. The petroleum engineers are the most numerous with 4175 students, followed by the metallurgical engineers with 3887, the mining engineers with 2223, and the ceramic engineers with 998. These figures include both undergraduate and the graduate students.

A total of 1224 students are enrolled in the graduate courses in the mineral engineering schools of the United States and Canada, which is about 25% larger than last year.

The available supply of mineral engineers for the mineral industries is indicated by the number of men who are likely to be candidates for bachelor degrees next June. These are as follows: mining engineers 646, metallurgical engineers 1215, petroleum engineers 1152, and ceramic engineers 336.

It is too early now to predict the June employment prospects for the graduates in mineral engineering, but already some of the men, particularly in mining in some of the eastern schools, have been placed. What the situation will be among the other mineral engineers is not yet indicated. *(Tables continued on next page.)*

TABLE I

Engineering Enrollment by Courses and Classes
United States and Canada, 1949-50
188 Schools

(From Journal of Engineering Education, *February, 1950, advance data)*

Courses	ECPD Schools	Freshmen	Sophomores	Juniors	Seniors	5th Year and Others	Total Undergraduates	Graduate Students	Grand Total
Mining	34	467	524	515	640	6	2 152	71	2.223
Metallurgical	45	493	625	793	1.014	201	3.126	761	3,887
Petroleum and Natural Gas	22	1,014	924	965	1,135	17	4,055	120	4,175
Ceramic	13	143	191	223	331	5	893	105	998
Total Mineral Engineers—U. S.		2,117	2,264	2,496	3,120	229	10 226	1,057	11,283
Chemical	102	3.226	3,701	4,207	4,684	1,574	17 392	2,584	19,976
Civil	130	4,668	5,855	6,931	7 877	1,804	27,135	1,974	29,109
Mechanical	126	6,356	8,322	10,768	12,944	4,368	42,758	2,874	45,632
Electrical	130	6,190	8,005	9,679	12,979	4,093	40 946	4,765	45,711
Other Engineers	52	7.025	6,420	7,403	9,332	2,059	32,239	3,820	36,059
Unclassified	74	6,926	1,081	211	55	1,677	9,950	546	10,496
Total Engineers ECPD Schools	141	36,508	35,648	41,695	50,991	15,804	180,646	17,620	198,266
Other U. S. Engineering Schools	39	5,355	3,910	4,382	4,707	2 927	21,281	165	21,446
Total U. S. Engineers		41,863	39,558	46,077	55,698	18,731	201,927	17,785	219,712
Total Canadian Engineers	8	1,218	1,174	1,617	2,319	328	6,654	167	6,821
Total Engineers U. S. and Canada		43,081	40,732	47,694	58,017	19 057	208 581	17,952	226,533

TABLE II

Engineering Student Enrollment, 1940-41 to 1949-50, Undergraduates and Graduates

Courses	1940-41 (1)	1944-45 (2)	1947-48 (2)	1948-49 (2)	1948-49 (2)	1949-50 (3)
Mining	1,978	224	2,459	2,632	2,256	2,223
Metallurgical	2,450	472	4,121	4,158	4,055	3,887
Petroleum and Natural Gas	2,877	376	4,665	4,147	4,533	4,175
Ceramic	843	190	1,108	1,214	1,206	998
Geological	792	?	?	2,777	?	?
Fuels	44	?	?	47	?	?
Specials	149	?	?	53	?	?
Total Mineral Engineers						
United States	....	....	....	13,769	....	11,283
Canada	....	....	....	1,259	....	....
U. S. and Canada	9,133	1,262	12,353	15,028	12,050	
Chemical	....	5,082	26,972		23,619	19,976
Civil	....	3,537	31,849		33,861	29,109
Mechanical	....	6,965	56,551		53,642	45,632
Electrical	....	5,934	56,408		53,774	45,711
Others	....	18,852	68,117		72,969	68,001
Total Engineers—Canada	....	....	....		....	6,821
Total Engineers—U. S. and Canada	114,116	41,632	252,250		249,915	226,533

(1) *Mining and Metallurgy*, April, 1948.
(2) *Mining Engineering, Journal of Metals*, and *Journal of Petroleum Technology*, August, 1949.
(3) *Journal of Engineering Education, February*, 1950, advance data.

TABLE III

Graduate Engineering Students 1949-50—U. S. and Canada

(*From* Journal of Engineering Education, *February*, 1950, *advance data*)

	Masters	Doctors	Degrees Conferred 1948-49 M.S.	Ph.D. or Dr.
Mining	62	9	27	2
Metallurgical	566	195	197	34
Petroleum and Natural Gas	113	7	39	
Ceramic	86	19	37	11
Total Mineral Engineers ECPD	827	230	300	47
Chemical	1,978	606	748	151
Civil	1,767	207	743	34
Mechanical	2,593	281	864	40
Electrical	4,105	660	1,080	72
Unclassified	546		22	
Other Engineers	3,263	557	1,026	73
Total ECPD Schools	15,079	2,541	4,783	417
Total Other U. S. Schools	161	4	15	
Total All U. S. Schools	15,240	2,545	4,798	417
Canadian Schools	163	4	47	1
Grand Total	15,403	2,549	4,845	418

TABLE IV

First Degrees Conferred, All Engineers, United States and Canada

1942-43	14,714
1943-44	11,155
1944-45	4,724
1945-46	8,219
1946-47	19,272
1947-48	30,018
1948-49	46,934 (x)

Data from *Journal of Engineering Education*.
(x) Includes 150 women; 148 in United States and 2 in Canada.

Shortage of Engineers Foreseen

A serious shortage of graduate engineers, beginning in 1954 and continuing until 1965 and later, has been indicated by figures released by the Bureau of Labor Statistics. According to the Bureau's figures, the number of engineering graduates in 1952 will fall short of the number of men which it is thought will be needed for actual engineering jobs. The Manpower Committee of the American Society for Engineering Education, at Northwestern University, has just completed a study of trends in secondary school and engineering college enrollments, and has noted a steady decline in such enrollments since 1946. In that year, those enrolled in engineering courses amounted to 8.6% of all high school graduates, while last year this figure declined to 3%.

Engineers in prospect—About 51,000 engineering graduates are expected in 1950. But by 1952, the number of graduates will have declined to 25,000, and 1957 is expected to hit a low point of 15,000. On the other hand, the Bureau of Labor Statistics sees an average annual need for engineering graduates of 22,000 by the year 1960, while the Engineers' Joint Council says that the Bureau's 1949 estimates foresaw only *half* the actual need.

The need for trained engineers is expected to continue expanding. Industry and government research projects, the fact that engineers tend to create the need for more engineers, and the tendency of employers to hire engineers for jobs that were formerly "nonengineering" jobs, all contribute toward the need for more graduates.

The ASEE, in noting the expected shortage of engineers in the late 1950's, says two factors can act to mitigate the prophesied lack of graduates: (1) an increase in the ratio of high school graduates who go to college, or (2) an increase in the ratio of freshman engineers to high school graduates. The first possibility seems more promising, according to the Society.

Northern Appalachian Salt

- Distribution
- General Character
- Production
- Trends and Potentialities

by John A. Ames

AMERICAN pioneers first discovered "commercial" salt in western New York State. Geologists gave the classically correct name of Salina to the salt bearing strata of New York. Rock salt occurs in rocks of approximately the same age and stratigraphic position as New York's Salina "group", to the south and southwest, in western Pennsylvania, eastern Ohio and northwestern West Virginia.

Sodium chloride and associated salts occur in brines throughout much of the same area as the rock salt. Brines also are found in areas well beyond the margins of that under which the rock salt lies, especially to the west in Ohio and to the south in West Virginia. The occurrence of the brines in the same area as the rock salt is almost always coincidental rather than indicative of a physical association.

Much of the brine used by industry is, of course, "artificial brine", i.e., a nearly saturated solution obtained by introducing fresh water into rock salt beds, then pumping up the brine which has reached a high degree of concentration. By comparison the natural brine is impure and of low concentration, so the artificial brine is becoming relatively more important in the Northern Appalachian Area. Much of the emphasis of this paper is directed toward rock salt.

Most of the data concerning salt in Ohio, Pennsylvania and West Virginia are based upon oil and gas well records. The accuracy of rock salt thicknesses as noted is questionable, in many cases, because variation in drillers' methods, very thin bedding and interbedding, and misidentification of minerals all add to the difficulty

Mr. Ames is assistant engineer of industrial development division of The Baltimore & Ohio Railroad Co., Baltimore, Md., and is a junior member, AIME.

The Columbia Chemical Division of the Pittsburgh Plate Glass Co. at Natrium, West Virginia—producing salt from deep-lying deposits through water-solution methods.

of obtaining correct records. In the case of natural brines few analyses have been made and practically no reliable records of flow volume are available, other than at wells specifically drilled for brine.

The rather intensive oil and gas drilling in Ohio has afforded data which were bases for the careful study by J. E. Pepper[2] on the State's salt. The boundary of the salt has been located within close limits, and the attitude of the top of the salt is relatively well established. The map best illustrates the location and extent of the subsurface rock salt. The rock salt lies under approximately 9100 square miles of Ohio.

The rock salt of Pennsylvania is not as well known as the shallower salt of Ohio and New York, but about 40 deep wells have recorded bedded salt in western Pennsylvania. The eastward extension of the salt is limited by the Appalachian structural front to which it probably extends, although the details of this boundary certainly are unknown. Rock salt is thought to lie under at least 15,000 square miles of western Pennsylvania.

West Virginia's rock salt is generally thick, yet its extent is not well known because the salt lies at relatively great depths. Some wells seem to have indicated the approximate edge of the salt as shown by J. H. C. Martens.[3] Dr. Martens also has made the provocative observation that the salt *may* be discovered at relatively shallow depths (about 1700 feet) in Hampshire, Mineral, or Morgan counties of West Virginia, or in adjoining parts of Maryland. About 3100 square miles of West Virginia are indicated to have rock salt substrata, and this area probably will be extended when the salt margin is known.

The position of the rock salt with relation to sea level is known only approximately; however, the contours as shown on the map are based upon the best information available.

It is almost futile to attempt to map natural brines unless a series of maps and sections is employed. Many localities have numerous overlapping, brine-containing zones which seldom can be delineated, because the zone limits are difficult to establish or even to define. Better commercial brines, on all counts, seem to be those located, generally, in southeastern Ohio and central-western West Virginia.

The *rock salt* generally occurs in lenticular units interbedded with shales, limestones, anhydrite, sandstones and other sediments in a complex relationship. Single lenses of salt may be small and thin or extensive and thick. While the individual salt lenses of the Northern Appalachian Area seldom are correlated from one locality to another, the Salina strata are remarkable for their persistent content of an appreciable amount of bedded salt. Aggregate thicknesses of salt range to over 400 feet in Ohio and Pennsylvania. Thick individual lenses are known in many areas and usually are confined to the zones of greatest aggregate thickness of salt.

Available analyses of commercial rock salt of the Salina strata in the Northern Appalachian Area are nearly all from New York State, and those, plus most of the analyses from other states, indicate that most of the salt is purer than 95% sodium chloride. The variation of purity usually is due to inclusion of insoluble impurities rather than to higher concentrations of soluble salts. This fact is important to potential producers, because those who use water solution methods of salt recovery can count on much of the impurity being left underground undissolved, and some of the suspended impurity will "settle out." In a negative way the same fact also is important to companies who mine salt, because they must seek a rock salt of high purity, as mined; and they are nearly always obliged to core drill to determine the true character of salt beds which may have been merely located by other drilling.

Many *natural brines* are thought to be entrapped sea water and are called *connate* brines. Regardless of origin the better commercial brines have been concentrated by natural processes subsequent to their "origin" in the sediments.

Concentrations of sodium chloride and other salts dissolved in natural brines vary greatly, and the degree of concentration is one of the important factors which determines commercial value of a brine. Other factors include comparatively shallow depth, rate or amount of flow and a generally satisfactory location as to market and raw materials. The salt-producing industry of the Northern Appalachian area still includes some operations in which sodium chloride is a primary product from natural brines. Associated salts are "by-products." Future natural brine processing plants probably will extract some of the now "by-product" salts as primary products, and if sodium chloride is extracted at all, it will be of secondary importance.

Southeastern Ohio and western West Virginia have strong flows of good natural brines at relatively shallow depths, usually in Mississippian

age reservoir sandstones. The brines in this area were the source of salt for the important pioneer salt industry of the early 1800's and still are active producers. The Kanawha Valley and vicinity has been, and remains, the focal point of the natural brine industries.

Production—No rock salt mine has been operated in Ohio, Pennsylvania or West Virginia, to date, chiefly because the salt lies at considerable depths. The salt is produced from either artificial or natural brines through wells. These brines may be processed and used as brines, or they may be evaporated to convert the dissolved salts to dry form.

The location of a salt-producing plant naturally is controlled by the location of commercial salt. Other economic factors do play an important part in the selection of a site, because thick beds of salt occur under such a large area (not considering special conditions required for shaft mining). Some of the additional vital factors which must be considered in the selection of a site for a salt or salt-chemical producing plant are: water supply and cost, power supply and cost, fuel supply and cost, access to adequate transportation facilities, strategic location in the market area, and a topographically suitable piece of land large enough for a plant and for potential expansion.

In 1948 Ohio ranked third among salt producing states with a total of 2,752,696 short tons. West Virginia was eighth with 246,732 tons, and Pennsylvania was not a producer during 1948. The United States production reached a record peak of 16,403,393 tons of salt in 1948.

About 19% of the total salt production reported by the U. S. Bureau of Mines[4] for Ohio and West Virginia was sold as evaporated salt. Artificial brine is *estimated* to be the "source" of about 93% of the salt reported for Ohio and West Virginia.

Trends and Potentialities—Salt always has been an essential food and has developed into a basic raw material. A unique study by R. N. Keller and the late T. T. Quirke[5], made in 1939, attempted to determine the ultimate geologic raw materials which enter into the production of 150 important industrial chemicals. While their study was more qualitative than quantitative, they seem to have analyzed the possibilities thoroughly. The first ten materials, in order of importance, on their list are:

(1) Water	(6) Limestone
(2) Air	(7) Sulphide ores
(3) Coal	(8) Natural brines
(4) Sulphur	(9) Petroleum
(5) Mineral salt (NaCl)	(10) Natural gas

The trend toward an over-all increasing volume of salt consumption, in the United States, seems firmly established. Per capita consumption has generally increased in the last 40 years from less than 100 pounds to about 225 pounds a year.

General growth of the chemical industry will continue to expand the amount of salt used, and the recent development in organic chemical production has particularly increased the consumption of the salt chemicals used in processing. New developments, such as those in metallurgy (recovery of titanium metal, etc.), continue to create new demand for chlorine and caustic.

Salt is a cheap raw material in the United States (national average of about $6.50 a ton). The use of improved mercury cells in the production of chlorine and caustic, plus other technical advances, have continued to maintain a relatively low cost for these chemicals. The cheapness of both salt and salt-derived chemicals is attractive and helps encourage expansion and development of new uses.

At present the sales of salt chemicals are lagging behind high 1947 and 1948 peaks, and an unbalanced situation is caused by a more consistent demand for chlorine and soda ash than for caustic. Increased over-all demand is easier to visualize than correction of this unbalance, because the combined chlorine, hydrochloric and soda ash uses continue to outstrip the demand for caustic, yet the volume of caustic ordinarily increases with that of the other chemicals, in their normal production. Some relief may be hoped for in the continuing development of new uses for the versatile caustic (especially such large scale uses as the fused salt pickle for metal descaling). The increasing use of metallic sodium will help to balance chemical production because chlorine is evolved, but not caustic, in the process.

Chlorine is becoming more and more important among the "industrial chemicals." Certain prognosticators who follow trends in the business world have long used sulphuric acid sales as a key or index of what chemical companies planned to do in the immediate future. The recognition of chlorine as a similar reliable index has become increasingly apparent.

Vast reserves of rock salt are known to exist in the Northern Appalachian Area. Gambs and White[6] estimate that Ohio has a total reserve of over 2200 billion tons of recoverable rock salt. Reserves in Pennsylvania and West Virginia also are of this order of magnitude, although not enough data are available to make a worthwhile estimate. Brine reserves are great, but no attempt to estimate the quantities is thought to be reliable.

The Salina salt of the Northern Appalachian Area is well located to serve much of the industrialized eastern United States. The competitive position of this salt, in the United States, seems assured by its location, and its products will help keep a large share of the chemical industry in the "east." The combination of coal, salt, and limestone perhaps is the most attractive association of mineral raw materials available to the heavy chemicals industry.

References

[1] Dana, James D., *Manual of Geology*, (First edition), 1863.

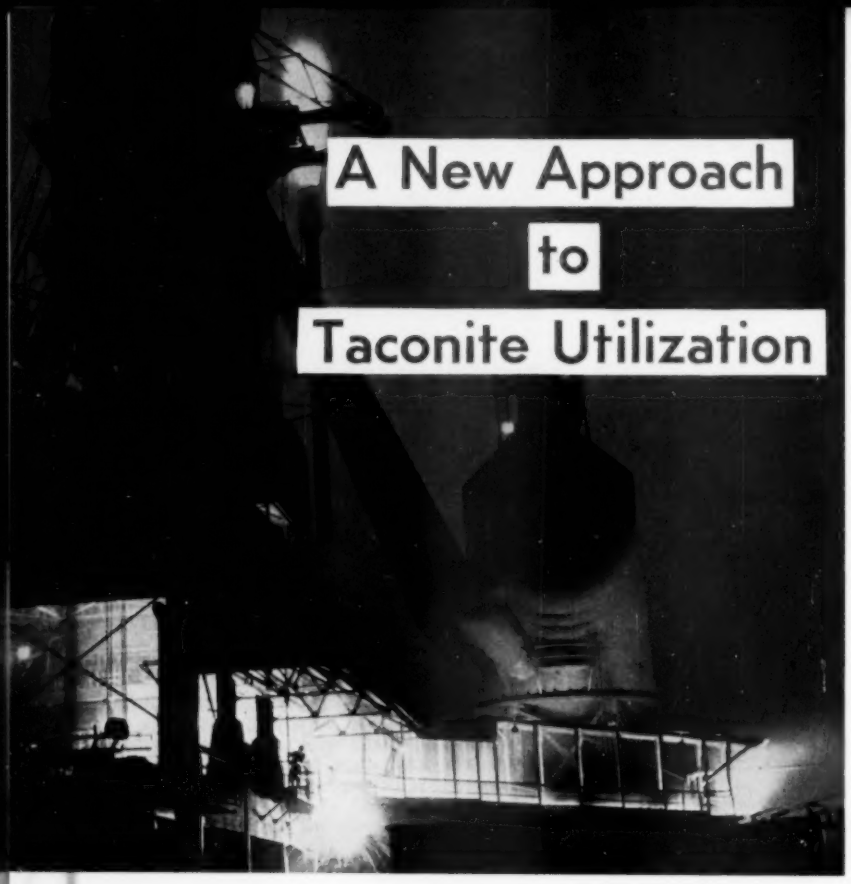
[2] Pepper, J. H., *Areal Extent and Thickness of the Salt Deposits of Ohio*, Ohio Jour. of Sci., vol. 47, no. 6, p. 225-239, 1947.

[3] Martens, J. H. C., *Rock Salt Deposits of West Virginia*, W. Va. Geol. Survey Bull. 7, 1943.

[4] Harris, F. E. and Tucker, E. M., *Salt Output in 1948 Almost 16½ Million Tons*, U. S. Bureau of Mines, Mineral Market Report, MMS. no. 1739, 1949.

[5] Keller, R. N. and Quirke, T. T., *Mineral Resources of Chemical Industries*, Econ. Geol., vol. 34, no. 3, p. 287-296, May, 1939.

[6] Gambs, G. C. and White, G. W., *Ohio's Mineral Resources III, Salt Reserves*, Engineering Experiment Station circular no. 49, Ohio State University, 1946.



A New Approach to Taconite Utilization

by John J. Howard

WE are approaching the depletion of our principal source of iron ore—the Great Lakes deposits, which have provided 85% of the nation's requirements for the past fifty years. This situation presents a threat to our standard of living and our position as a world power. Fortunately, in the Great Lakes region there are still tremendous quantities of potential iron ore in the form of the low iron, high silica rock called taconite. The economical extraction of iron from taconite will insure our future steel supply if no new deposits available to the United States even in time of war are discovered.

In the new process presented here, the iron is reduced directly by a simple method and then separated from the silica. The product is "feed," not to the blast furnace, but to the steel plant. This process requires very much less plant, less physical and chemical treatment, and less fuel and auxiliary materials than the conventional ore concentration-blast furnace method. In my opinion, this new, fundamentally different approach offers a better hope for the solution of the iron ore problem.

In the Lake Superior region there are many billions of tons of low-grade potential iron ore. The high-grade Lake Superior ore bodies are relatively small, localized spots within much larger areas of the iron formations which are composed of iron-bearing rocks called taconite. Taconite constitutes our tremendous potential reserve.

But taconite contains only 25 to 30% iron and 50% silica, so it is unusable in its present form as feed to the blast furnace for the production of pig iron. Blast furnace ore should not contain over 8.5% silica. To make taconite available as an iron ore for our present practice, the silica content must be lowered, the iron minerals must be concentrated, and the concentrates put into suitable physical condition before they can be used to make iron. Practically all our major steel companies or their ore mining companies now have in progress large-scale research projects to develop feasible methods of manufacturing shipping ore from taconite. In the Great Lakes area the iron ore problem has become the taconite problem, and the security and welfare of the nation may well depend on its solution.

Mr. Howard, former vice-president of E. J. Lavino & Co. in Philadelphia, is now retired and living in that city. He is an AIME member.

There are varieties of taconite but as a brief, inclusive description it can be considered as a dense, hard rock composed essentially of quartz (generally the variety chert), and oxides, silicates, and carbonates of iron.

TACONITE is unusable as blast furnace feed in its present form. The author suggests a new, simple method of reduction which would send metallic iron directly to the steel plants.

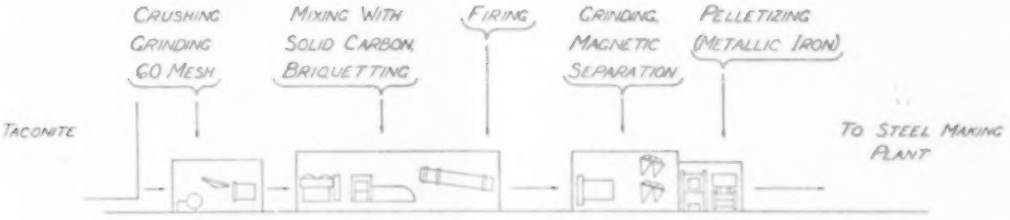
Technologically, an important classification of taconites divides them into magnetic and nonmagnetic varieties. In the magnetic taconite most, or at least a sufficient part, of the iron present is in the form of magnetite—the magnetic iron oxide. In the nonmagnetic taconites the iron occurs mostly as hematite or limonite, the nonmagnetic oxides, and to a lesser extent as iron silicates and carbonates which in their natural state are also nonmagnetic. The magnetic taconites can be ground and the iron mineral separated magnetically from the silica. To effect a comparable separation in the nonmagnetic variety, it would have to be roasted to convert the iron minerals to magnetite, or some other method of separation must be used.

The Conventional Approach—In either case, since the iron minerals are finely disseminated and locked in the quartz, the rock must be crushed and ground extremely fine to prepare it for a concentration process. Fig. 1 is a photomicrograph illustrating the finely disseminated nature of the iron ore minerals. Practically all the methods now being used or proposed for the solution of the taconite problem are along the lines of conventional ore dressing. Magnetic taconite is naturally favored because of the possibility of magnetic separation. But the magnetic taconite does not constitute nearly as large a reserve as the nonmagnetic taconite, so eventually a process to recover the iron mineral from that variety must be developed.

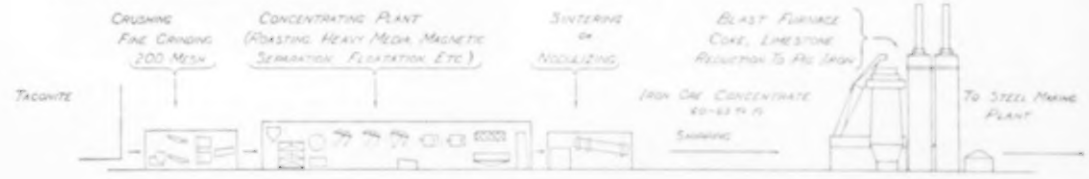
The conventional approach begins with crushing and fine grinding the ore to minus 150 or 200 mesh to unlock the iron ore minerals from the siliceous gangue. Then come various physical separation procedures (or combinations of them) among which are mechanical, gravity, flotation, and magnetic methods. Magnetic separation seems at this time to be receiving the most attention. The nonmagnetic taconite can be roasted to make it amenable to magnetic separation. The magnetic concentrate is then agglomerated by some type of sintering, nodulizing, or briquetting before it can be fed to the blast furnace. Only as a final agglomerated concentrate can the material derived from taconite be considered comparable with present crude high-grade ore.

The plants treating taconite (if eventually it becomes our major source of iron) will be of tremendous capacity, for three tons of taconite are needed to produce one ton of usable furnace ore. The present high-grade ore is simply quarried from the earth and shipped to the furnace. But if we must mine three times as much taconite and then interpose a new, tremendous

The New Approach



The Conventional Approach



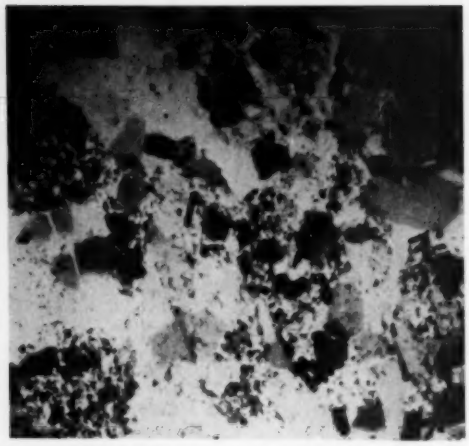


Fig. 1 — Photomicrograph of thin section of taconite shows intimate distribution of iron oxide in quartz. Black is iron oxide, white and gray is quartz. Magnification = 96x.

manufacturing plant to get the same result, it is safe to assume that the economics of steel may be profoundly affected. The solution to the taconite problem, as its initial stages are now taking form, is mainly in the hands of the ore mining men. Their task has been to supply blast furnace feed to the steel industry. To extend their reserves they have done a certain amount of beneficiation of intermediate grade ore (not taconite) to supplement the main bulk of direct shipping ore. It is thus understandable that the present approach is along conventional lines.

But the change from a supply of 50%-iron, 8%-silica ore to one with 25 to 30% iron and 50% silica is so drastic that the problem can hardly be relegated to one division of the industry. The situation calls for a complete re-evaluation of the steel making process from mine to ingot.

A New Approach to the Problem—Experimental work carried out by the writer during the past five years points to an entirely new method for winning iron from taconite. The premise upon which this proposal is based follows.

The most satisfactory physical condition for chemical reaction is the gaseous phase because the reagents are miscible in all proportions and molecular contact is possible to the greatest extent. To approach gaseous phase conditions in reactions between solid reagents, the reagents are comminuted as far as economically possible, thoroughly mixed, and pressed together. The maximum surface is then obtained for reaction, the surface of the reacting solids are as close to each other as possible, and when the proper conditions are obtained the reaction can take place with maximum velocity. By comminuting, mixing and pressing the solid reagents, the best physical condition for chemical reaction is approached, but never reached.

Instead of following customary procedure for removing the gangue from the ore to produce a high-grade product, which, after expensive treatment, is still an iron ore that must be reduced in the blast furnace, this new proposal reduces the iron oxide to metal directly from the taconite, and the metal is recovered by well-known methods of separation.

This process, stated in its bare essentials, is as follows: Grind the taconite to only moderate size (minus 40 mesh); mix with it the required amount of ground coke or coal for complete reduction; press the material into a briquette, and heat. The resulting product will be a rather friable lump consisting of spherical globules of metallic iron loosely held among grains of silica (see Fig. 2). This material is easily ground and the iron globules magnetically separated. The briquettes can be heated in either rotary or tunnel kilns. It has been found that 2500F is sufficient for reduction with the time required for complete reduction only one hour. The iron is reduced from oxide and collects in globules, but since the silica does not melt below 2900F the process is essentially a completely dry solid state reaction. The iron globules are essentially pig iron. There are certain methods by which the iron composition of the product can be changed, and also for increasing the globule size, such as "sweetening" with a high iron content material which has only silica as gangue.

We have here a process requiring a plant comparable in investment and operating cost to those proposed for making blast furnace feed from taconite, but this new process produces *metallic iron* for feed to the *open hearth steelmaking* furnace.

Instead of grinding to 200 mesh as in conventional ore dressing methods, the tacolite is ground to only 40 mesh. Thus, instead of separating very fine iron oxide from the silica and following this with sintering or nodulizing to make it suitable for a blast furnace, our new proposal is to heat the coarser taconite-coke mixture at a controlled temperature. This temperature is kept well below the melting point of

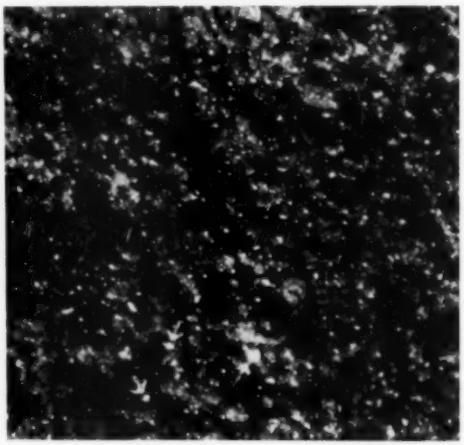


Fig. 2—Photo (enlarged 14x) of surface of briquette made of ground taconite and coke, mixed, pressed, and fired for 1 hr at 2500F. Arrows indicate globules having composition of pig iron held in a friable matrix of silica.

the silica component, but high enough to reduce 100% of the iron oxide to metallic iron. From the resulting material we can separate the fine iron shot and pelletize it by a simple process for direct use in the open hearth furnace. Taconite contains essentially iron oxides and silica, and because of this simplicity of composition the fired briquette after cooling is friable and readily broken up, making possible the separation of the iron globules from the silica.

Direct reduction methods yielding sponge iron are known and have been tried, but the proposal presented here is in a different category. Unlike sponge iron and similar products, the metal made in this new process is similar to pig iron chemically. This new proposal is a radical departure from long established practice and brings a fresh point of view to an art which has been essentially changeless for so long.

The writer does not propose in this paper to detail methods of using the approach described but rather to suggest, by specific examples, the broad outlines of practical procedures. The procedures may be altered in accordance with variables introduced by factors peculiar to each individual case—factors which must be evaluated in the field but which do not change the fundamental principles involved.

As one example, consider the taconite shown in Fig. 1 and the brick (Fig. 2) obtained in the treatment of such ore. The taconite and coke were separately crushed and ground to substantially all passing a 40 mesh Bureau of Standards screen. On size analysis, the ground material showed all through 10 mesh, about 1.5% on 40 mesh, and about 50% through 100 mesh. The relative amounts of coke and taconite were calculated from their respective analyses. The taconite analyzed about 45% Fe_2O_3 (equivalent to 31.5% when calculated to metallic Fe) and about 50% SiO_2. Theoretically, one lb of Fe_2O_3 requires 0.225 lb of carbon for reduction to metallic iron, therefore, the Fe_2O_3 in 100 lb of taconite required 45 times 0.225 lb or 10.125 lb of carbon to yield 31.5 lb of pure metallic iron. Molten iron will dissolve or combine with up to 4% of its weight of carbon, hence an additional 4% of 31.5 lb or 1.26 lb of carbon are theoretically required, making a total theoretical carbon requirement of 11.385 lb for 100 lb of taconite. If the source of carbon is coke containing 90% fixed carbon, then 11.385 lb divided by .90 or 12.650 lb of coke are required. It is advantageous to use an excess of carbonaceous material to assure complete recovery of the iron, and in the experiment being described 20 lb of coke were used to each 100 lb of taconite.

The calculation was made on the assumption that the iron in the taconite was present as Fe_2O_3. Actually it is immaterial whether the iron occurs as Fe_2O_3, Fe_3O_4, or $FeCO_3$ so long as sufficient carbon is present to effect reduction. As a matter of fact, the analysis of the final product can be controlled to some extent by the proportion of carbon in the mix, a deficiency of carbon resulting in lower C metal, with some loss in recovery because of unreduced oxides in the fired brick body.

The proper proportions of the ground taconite and coke were intimately mixed, a small amount of water and organic binder (sulphite pitch in this case) were added, and the mixture pressed into brick, which was heated to 2500 F for one hour in a direct oil-fired pot furnace. Any temperature in the range of from 2450 F to 2750 F is feasible. Below 2450 F there is little collection of the iron in globules. Variations in the time at reaction temperature also offer a means of controlling the final product and process without altering the fundamental principles. A range of from 15 minutes to 60 minutes is feasible. The time-temperature factors determine the size of the metal globules obtained—60 minutes at 2700 F, for example, will tend to cause the molten iron to drain from the bricks.

After cooling the brick which has been heated to 2500 F for one hour, it was found to consist of globules of metallic iron in a friable matrix of cristobalite (a crystalline variety of silica resulting from inversion of the quartz) as shown in Fig. 2. On the test in which the Fig. 2 product was obtained, practically all the iron was recovered by wet-magnetic separation. The recovered metallic iron had an analysis: 92% Fe, 2% C, 6% Si O_2. The silica content varied with the temperature used in the tests ranging from 1.5% to .1%, but all the phosphorus contained in the mixture was reduced in the metal. The manganese varied in the metal according to the manganese content of the ore. Sulphur is present depending on the grade and kind of fuel used.

The experiment described above is one of a series of about 100 in which variables such as coke proportions, temperature, time to reach temperature, and time for which temperature is held were investigated. The results were uniformly good—pig iron readily recovered by wet-magnetic separation from a friable cristobalite matrix with good yields. The composite result of all the tests points to the direct reduction process shown diagrammatically in Fig. 3.

Discussion of Results

When taconite, alone or enriched, is mixed with coke, pressed into a briquette, and the briquette fired, the resultant briquette consists of matrix of silica containing discrete particles of small iron shot. This iron is then separated from the silica. Two methods of separation were investigated. (1) Grind the friable briquette and separate the iron shot and silica by wet-magnetic separation. The iron recovered analyzed 92% Fe, 2% C. (2) Grind the friable briquette and separate the iron shot and silica by flotation. Preliminary tests were promising.

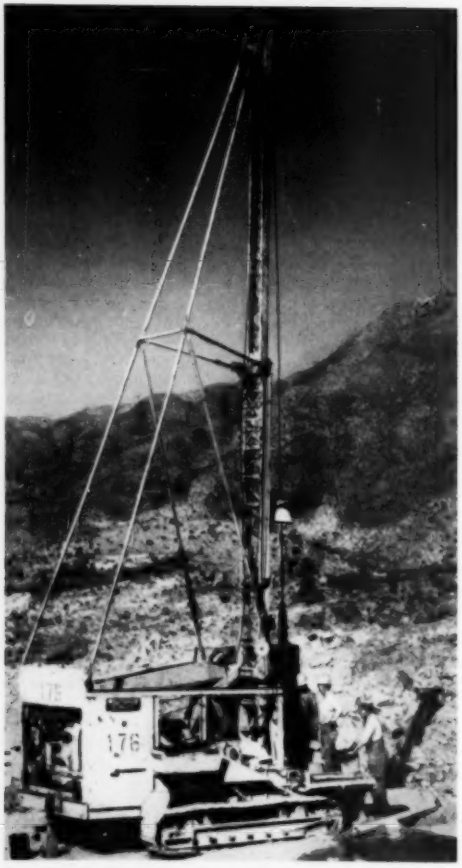
Reduction was essentially complete at 2450F. Increasing the soaking temperature to 2600F gave a slight increase in the size of the iron shot.

The enrichment of the taconite ore gives a briquette containing a higher percentage of iron than taconite alone. After firing the briquettes, the iron shot progressively increases in size as the ore is enriched.

The fired briquettes are rather easily crushed to a coarse, sand-like mass. In this state, some of the iron shot is attached to silica grains. It is necessary to unlock this iron shot from the silica grains before a mechanical separation can be carried out. This unlocking can be accomplished by fine grinding. Tests indicate it may be possible to facilitate this fine grinding and unlocking by rapid cooling of the hot briquettes, thereby heat-shattering the silica grains.

Morenci Drilling Practice Up to Date

by L. Ormsby and H. Lines



A Bucyrus-Erie churn drill mounted on a Caterpillar tractor is shown at work drilling blast holes against the background of Arizona's hills.

DRILLING and blasting practices in the Morenci open pit have undergone considerable modification in recent years. Changes in the character of the ground being mined, modifications of working conditions, and continuous experimentation have been the contributing factors.

At Morenci about 90% of the muck is hauled by trains and the remainder is hauled by trucks. The early blasting practices were in large measure restricted by the problems of track handling, which in that period was done with large track gangs, track shifters, and by occasional use of bulldozers. With the adoption of panel track and its resultant improvement in track handling, it became customary in the hard rock areas to remove the track entirely before blasting. This gave the drilling and blasting supervisors an opportunity to concentrate solely on blasting to produce desired fragmentation at minimum cost without being concerned as to track damage. Accordingly, experimentation was carried out on such factors as hole spacing and depth, length of toe, unequal loading, springing of holes, and hole diameter. Practically all of the drilling is done after banks are faced up. Under that condition, with proper hole spacing, it has been found that a toe of 12 to 13 yd will break well in the average Morenci rock. This, of course, applies to 50-ft banks and with a hole spacing of from 7 to 8 yd depending upon hole diameter. At one time, the approach to the problem was through decreasing the burden on the hole by decreasing the distance between holes as well as shortening the toe, but that practice resulted in poor fragmentation in addition to increasing the drilling costs. The burden was gradually in-

Messrs. Ormsby and Lines are, respectively, mine superintendent and drilling and blasting foreman at the Morenci mine, Phelps Dodge Copper Corp., Morenci, Arizona. Both are AIME members. **This paper was presented before the Arizona Section, AIME, Nov. 14, 1949.**

creased until bad shots resulted, but it was found that up to a certain point, as determined by track throwing efficiencies, heavier burden made for better fragmentation. In other words, the more powder that could be put in a hole with proper depth relationship, the better the over-all results. However, no improvement in the efficiency index of tons broken per pound of powder used has resulted. On the other hand, the tons broken per foot of churn drill hole has increased from an average of 33 in 1940 to 58 in 1949. The loading ratio varies roughly from .7 of a lb of powder per cubic yard of burden in the softer areas to 1.25 in the harder rock. This loading ratio is based on burden in front of the hole and does not include back-break. It is interesting to note that the present cost of powder per ton broken compares favorably with figures achieved in 1940. This is due, however, to the use of cheaper grades of powder as developed by the manufacturers.

As it became evident that the chief economies in breaking ground could be effected by lower drilling costs, experiments of springing 9-in. holes to increase powder capacity were carried out. These experiments, begun in 1946, were continued, and the advantages of a larger powder capacity per hole was demonstrated. But the springing operation in itself was unreliable in that it was impossible to predict just what increased hole capacity would result. Because of that fact, it was concluded that larger holes would be desirable. Therefore, in 1948 two churn drills capable of drilling 12-in. holes were purchased. These two larger drills were tested in various parts of the mine for a limited time in comparison with 9-in. drills. The results obtained are tabulated below:

Type of Drill	Character of Rock	Ft Per Shift
Large, with 12-in. bit	Hard	61.3
Small, with 9-in. bit	Hard	43.3
Large, with 12-in. bit	Medium	67.8
Small, with 9-in. bit	Medium	61.4
Large, with 12-in. bit	Soft to Medium	87.9
Small, with 9-in. bit	Soft to Medium	74.1

Some tests were also made using the larger drill with a 9-in. bit plus a 1000-lb sinker bar. These tests indicated that about 30% more footage might be expected, but the longer stem was difficult to handle and the drawback of the small hole diameter still remained. The above tests showed that the bigger drill could drill the 12-in. holes without sacrifice in drilling speed. It must also be pointed out that the larger drills showed definite advantages in the drilling of hard, fractured rock. The rate of drilling was much greater and fluctuations in drilling speed were at a minimum so that holes could be scheduled for shooting with a reasonable degree of accuracy. Another advantage of the larger powder capacity of the 12-in. holes was demonstrated when establishing new benches on development work. Formerly, to establish new levels, a pilot road was drilled with jackhammers and cleaned off with a bulldozer. It was then widened with wagon drills until the toe on the bank was reduced to 12 yd. During the past year, it has become the practice to shoot a double row of 12-in. holes with toes as long as 20 yd without sacrifice in fragmentation and with little or no secondary work remaining on the toe.

In 1949, 12 additional large drills were acquired. At present, 14 of the operating drills are the large type and 16 are the smaller type. The larger drills are being operated in the harder sections of the pit. As a result of this allocation of drill types on the basis of ground character, footage obtained per drill shift has increased from an average of 79 in 1948 to 86 in recent months. It is pertinent at this point to make brief comment on bit costs. For the larger drill, bit costs alone, which include steel loss and sharpening costs, are twice the similar cost items on 9-in. drills. The 12-in. bits are drilling about 10% more footage per sharpening. The over-all increase in bit cost of the larger bits is about 80%, which represents about 6% of the total cost per foot drilled.

The problem of hole spacing and loading ratio for drop cuts was taken up in the paper of March 21, 1947. Some shots were then being tried

with 20-ft hole spacing on 9-in. sprung drill holes and with a 1¼ loading ratio. This practice was later changed by substituting 12-in. holes with somewhat better results. However, no full drop cut shots have ever been very well broken. At the present time, a drop cut is being developed using 18-yd trucks and shooting to a faced-up full 50-ft bank. This operation appears to be successful, but final data will not be available until experience has been extended.

All of the data which have been presented heretofore are applicable and were derived in a rail-shovel operation. That operation has the limiting factor of a track-throw balance. In other words, even though it may be possible to break a toe of more than 13 yd, the economics of such an operation would be questionable in that it would be necessary to make a small additional track-throw to face up. Further, the amount of burden and back-break permissible on any blast is limited because of bench widths in normal open-pit rail operations. In a large truck haulage job with its greater flexibility, there would no doubt be opportunities for savings on drill footage compared with those possible in a rail-shovel operation. At Morenci a very small percentage of the tonnage is moved by trucks, but, nevertheless, opportunity has been presented for experiments along the lines of improving churn drill footage efficiencies.

Secondary air drilling and blasting—The secondary air drill footage per year represents an interesting development in the Morenci open pit, and is best illustrated by a yearly comparison of total secondary air drill footage to over-all daily production.

Year	Ft Drilled	Average Daily Production (Tons)
1940	388,230	37,000
1941	509,470	57,000
1942	458,669	87,200
1943	401,090	112,800
1944	167,301	99,500
1945	132,301	71,200
1946	103,248	100,000
1947	144,808	111,500
1948	100,560	114,100

The years 1940, 1941, 1947, and 1948 represent considerable development and opening of new areas, and are probably most directly comparable for secondary drilling results. With a remembrance of mining conditions during the last war, a glance at the above chart gives rise to the speculation as to what the normal course of air drill progress would have been had the war (with its resultant shortage of men and materials) not intervened. Efforts at Morenci have been directed toward reduction of secondary air drilling for the very obvious reason that costs in relation to ground breakage obtained are disproportionately large. No advances have been made in that operation which are comparable to present underground progress. The drilling practices and the footage per shift have been comparatively static with the result that there has occurred an increase in costs per foot drilled due to the effects of higher wage rates and increased supply costs.

The air drill needs in an open-pit mine are not the same as in underground mining, and although the same general equipment is used a much greater degree of mobility for both men and machines is demanded. Wagon drills, presently in use, give a good account of themselves when they are set up and operating, but the individual drilling jobs are small and a large amount of time is consumed in moving machines and air and water lines between locations. Problems incident to air supply have been eliminated in some measure through the use of truck-mounted 315 cfm air compressors.

Blockholing and mudcapping — In 1947, the practice was adopted of using mudcapping entirely on boulders set back by shovels. A standard charge of .7 lb of powder per cubic yard of boulder was established. This practice was estimated to be about 30% cheaper than blockholing under conditions prevailing at that time. In 1948, however, two 315 cfm portable air compressors were purchased and air availability was so improved by their use that it was found that boulders could be blockholed at approximately the same cost as for mudcapping. Inasmuch as mudcapping presented certain hazards due to flying rock, it was decided to abandon that practice and return to the blockholing method for the breaking of boulders.

Conclusion—In the above statistics and observations, it can be seen that the possibilities of large blasthole drilling have not been fully explored at Morenci. A considerable amount of experimentation remains to be done. The most that can be said is that improvement in fragmentation is evident and that there is much promise of further gains. Certainly, no revolutionary results are anticipated, but the small day-to-day trials and errors are definitely leading to increased efficiency in the drilling and blasting operation.

Specifications of Churn Drills Used in the Morenci Open Pit

	9-In. Drills	12-In. Drills
Weight without tools	24,000 lb	45,300 lb
Height	41 ft	51 ft
Width	8 ft 1¼ in.	11 ft 3 in.
Length with added deck	22 ft 6 in.	25 ft 9 in.
Length:		
Bit	6 ft	6 ft
Stem	6½ in. by 20 ft	8¼ in. by 21 ft
Socket	6½ in. by 4 ft	8¼ in. by 5 ft
Weight:		
Bit	500 lb	900 lb
Stem	2210 lb	3850 lb
Socket	290 lb	500 lb
Total	3000 lb	5250 lb
Tool Square	5 in.	5½ in.
Motor	20 hp	40 hp
Cable	⅞ in.	⅞ in.

Incentives for the Mining Industry

by Donald B. Gillies

The fundamentals of human nature don't change much from generation to generation, or even from century to century. Except for the spur of necessity and the lure of reward and adventure, few of us would bestir ourselves unduly. The general welfare has little appeal to the average individual. Its promotion comes about mainly as a by-product to individual efforts directed at more personal benefits and satisfactions.

In discussing incentives for the mining industry, we really are talking about incentives for people who devote their energies and resources to mining. The vigorous and productive mining industry as we have known it was the product of the varied incentives we have known in the past: the lure of great financial reward if you struck it rich; the thrill of romance and adventure in the search for mineral wealth, usually along the frontiers of civilization; the satisfaction of developing a great, productive enterprise by the application of skill, courage, and determination in the face of obstacles. Back of the prospector and engineer were other venturesome persons willing to take a flyer with their savings in a grubstake, or in stock in a promising mining venture, hoping for large returns, but reconciled to take a loss and try again with the next opportunity. It is free enterprise—a chance for high profits, but a chance also of total loss—that created the great mining industry of this country and of the world. Free enterprise has given us, in the United States, the greatest productive system in the world, the highest standard of living, the most abundant life. The lure of gold—whether from the ground or merely incidental to the discovery and development of our mineral resources—pushed our frontiers westward across the country and northward into Canada and Alaska far in advance of the staid course of agriculture and commerce. No one guaranteed success to our forebears as they risked life and fortune in developing a new country. Self-reliance was the backbone of our economic and spiritual progress and achievements. Our neighbors had little time to spare from their own problems. And though there was a willingness among the pioneers to help one another, they didn't lean too much on one another.

Then wars came. Our people were forced into closer cooperation for safety and protection. The wastes of war impartially imposed burdens, risks that were not chosen, losses that could not be anticipated, and disasters that were crushing. Sheer necessity drove our people successfully through every war in which they engaged. And in each new war the use of minerals played an increasingly vital role.

Hand in hand with the cost of past wars and of possible future conflicts came the burden of taxation. This burden has become a millstone which threatens to crush all our efforts to get back into the life I knew in which one was free to choose, act, achieve, and hope for reward. Piled on top of these costs are the additional severe burdens now being imposed on the taxpayers to support all sorts of schemes of the welfare state—which is being sold to the masses by clever propaganda of the do-gooders and the politicians who promise government support as a substitute for individual enterprise.

In creating the standard of living which we have attained—which still, on the average, leaves much to be desired—and in developing the devices for our national protection, we have become absolutely dependent on a continuous flow of minerals from their sources in the earth to the industries which process them into useful products. Without minerals we would be helpless.

Mr. Gillies is a mining consultant for the Republic Steel Corp. He was AIME President in 1939.

Our mounting needs have brought us to an expanding rate of extraction and utilization of minerals which makes the past only a poor guide to our future needs. A rapidly increasing population, combined with an increasing per-capita consumption, has changed our ideas of adequate mineral reserves. Estimates of our needs have risen greatly in even the past decade. Added to this, the tremendous inroads of World War II on our most accessible supplies have left many of our mineral reserves in a precarious position. With threats of a third war ever before us our mineral situation assumes even greater seriousness.

This brings me to the real question back of our topic here: "how can we assure ourselves of adequate, continuous supplies of the mineral raw materials which we must have to survive?"

There are these who will say that "times have changed"; that this question has now become a problem that only government can handle; that "free enterprise" is obsolete; that the old incentives no longer apply in our modern society. They are the exponents of statism—the cult that would make all men the servants of the government, and abandon our heritage under which government is the servant of the citizen. This cult would make men dependent on the "state" —actually their neighbors—not on themselves.

I must agree that "times have changed" a great deal. We have advanced farther than many realize along the road to collectivism. But from the example of socialistic societies elsewhere in the world, and from my long acquaintance with the characteristics of human nature as I have observed it in various parts of the world, I remain convinced that in the long run people can be moved to real creative and productive effort only by the hope of individual reward and not by any new-fangled incentives. If we in America expect to maintain and improve our living standards, we dare not let the State take over. We must maintain "free enterprise", the open door to opportunity, where energetic men who take risks can hope for rewards.

It is evident that the search for new mines is no longer the simple task of the lone prospector. The easily discovered mines probably have largely been found. We must depend, in the future, on great ingenuity in penetrating the cover of rock or glacial debris that may cover valuable ore deposits. We must also rely more and more on lower grades of ore that require expensive processing to make them useful. The cost of exploring and bringing a mine into production is now beyond the resources of most individuals or small groups of men who once could afford to take a "flyer" in a mining venture. In general, only large established companies, with trained personnel and ample resources, can now afford to take such ventures. And if an individual or a small syndicate finds something worth while, they are almost forced to look to some large mining company to do the necessary developing. Small mines will rarely grow into big ones in the hands of those who discover and first develop them. The odds and the demands for large capital are too great.

It is not the risks of mining, as such, however, that are the deterrents to exploration. It is rather the near certainty that the financial returns—whatever they may be—will not be worth while. The government's "take" is too great to leave a substantial reward for those who have taken the chance and in addition suffered the ever-present headaches and heartaches.

The investor must have a real chance to recover his full investment, and to make a profit commensurate with the risk taken. But the tax gatherer now begins taking his cut long before there is any assurance that there will be any net profit on the enterprise. Did you ever hear of the tax collector taking some share in the loss when that occurs?

I have said enough already to make plain to you that I find little place for government as a partner in the mining industry. I believe the contributions of government to the industry can best be made by supplying basic data and statistics on geology, on the technology of mining, and on ore treatment. These tasks are generally well done by the U. S. Geological Survey, the several state surveys, and the U. S. Bureau of Mines, at a modest over-all cost. Government can also contribute by the enactment and proper administration of fair labor laws and land laws; by sensible tariffs that protect our mines from the whims of foreign currency manipulation and from foreign governmental controls over workers, production and prices, without regard to the free market. Also, I believe government can do more to stimulate new mineral exploration, development and production, by amending the tax structure and improving its administration, and so restore, insofar as is possible, that encouragement to investors that is vital in stimulating the flow of new capital into mining.

I firmly believe that only by permitting proper incentives to venture capital is there any hope of our returning to the job of finding and developing mineral supplies in the quantities we must have to maintain and expand our position with its attendant responsibilities among the nations of the world.

As you all are aware, some of our once-rugged miners believe that Federal subsidies are the way out of their troubles. Farmers have price supports and get paid for conservation practices, so why not miners, they imply. They have sponsored several bills in Congress, the latest of which is S.2105, of which more will doubtless be heard in the next few months. A taste of "premium prices" during the war, when there was some reason for them, seems to have whetted their appetites, but dulled their senses. It is hard to return to "rough feeding" and "slim pickings". The argument is made that certain metals from marginal ores will be lost forever if subsidies are not granted to stimulate their recovery. Perhaps that is true, but the subsidy would only create a new and leaner margin beneath which other ores exist, which in turn would be lost unless greater subsidies were forthcoming, and so on, *ad infinitum*. Never can the mining industry retain its strength and self-reliance if government subsidies become its "props."

The "rugged West", which has been the backbone of our nation's vast metal mining industry, grew great with the development of mining under our free enterprise system. The going was sometimes tough and hazardous, but life was vigorous and venturesome, and great mines were developed for the incalculable benefit of our people. For this industry now to give up its freedom for the sake of "handouts" is to trade off its "birthright for a mess of pottage"; to give up the free air of self-determination for government rules, regulations and regimentation; in short to march straight down the road to Nationalization. To give governmental agents the power to grant mineral subsidies, cannot fail to lead to eventual abuse, for laws cannot be devised to fairly control the payment of mine subsidies, exploration incentive payments, or whatever you call them, as between potential beneficiaries. Mineral deposits and mines are too varied and complex to permit any uniformity of subsidy treatment which would presume to bring them within comparable margins of profit.

While I can sympathize with those who look to

government subsidies—which in reality, are but "gifts from the neighbors"—as a way out of their immediate difficulties, I was never more certain of anything than I am of this: that subsidies would create far more problems than they could possibly solve, and would result in damage to the whole mining industry that might never be corrected. The whole farm subsidy program, with its controls, threatens the rapid demoralization of a large segment of a once sturdy and self-reliant element of our population. It has permited appalling waste of farm products at the expense of consumers. Recently, it has been heartening to find that many farmers have at least awakened to the insidious whirlpool into which they were being drawn by some so-called farm leaders and political savants of our country. They are saying that they want no more of the nonsense of farm subsidies, price supports and other special benefits at the expense of the general public.

It is my opinion that only through concerted movement by the entire mining industry, can a sound program be set in motion which will remove the deterrents which now retard exploration and development at the hands of these most capable of doing it. Such a program would stimulate the flow of new capital by these and others would be happy to take the risks of mining in return for a fair break from the tax collectors.

Included in this program should be an appeal to Congress and to the State Legislatures to permit the tax-free operation of new mines for a period of three to five years. Canada now gives new mining ventures an initial three-year exemption from corporation income taxes. Another effective example, taken two years ago by a State, is the Michigan law which exempts newly-discovered ore from ad-valorem taxation for a period of ten years after discovery, or until it is included in an operating mine.

A few years ago we heard, from high places in government, the statement that we were rapidly becoming a "have-not" nation. Exhaustion of the high-grade open pit ores of the Mesabi Range in Minnesota was in the offing with no new fields of promising adequate supplies of direct shipping ore in sight. True, there were known to be vast tonnages of low-grade iron-bearing rock in Minnesota and in the Michigan-Wisconsin ranges, but with the tax situation as it was, which put ore-in-the-ground on the tax rolls as soon as it was shown to have value, there was no incentive for the mining companies to attempt to develop means to produce a high-grade product from this Taconite. Prior to 1937, largely through the efforts of E. W. Davis, Director of the Minnesota Mines Experiment Station, a brilliant and winning fight was started in the Minnesota Legislature for tax relief that would serve as an incentive to the mining industry to develop the Taconite as a source of high-grade manufactured iron ore. After a long period of hard work, the legislature was convinced of the need for such relief. A bill was passed and approved April 22, 1941, providing special and lenient tax treatment for Taconite operations. This provided a strong stimulant to the potential development of a great Taconite concentration industry. Almost immediately, promising Taconite-bearing land was picked up by lease or otherwise, and research began to develop methods of beneficiation by which a high-grade furnace feed might be produced. Since then these lands have been extensively drilled and great strides have been made in the various laboratories and pilot plants working on the problem of Taconite beneficiation.

These are types of incentives that are possible and practical in a broad effort to improve our natural resource position.

Expenditures for exploration, development and scientific research should be deductible as normal operating expense, and not required to be capitalized and recovered through depletion allowances. Also depletion allowances should be liberalized to permit full and rapid return of capital value of mines. There should be full allowance for capital recovery in assessing any income taxes, and ample provision for offsetting losses against profits over a period of years. Modification of tax laws to treat income from mines as capital gains and subject to the existing tax limitation thereon, doubtless would greatly stimulate the flow of venture capital into mining enterprises. Double taxation of dividends is an obvious deterrent which should be promptly eliminated. Severance or excise taxes, freight taxes and the like are especially burdensome The American Mining Congress has repeatedly given expression to most of the above and to other tax proposals which, if enacted, would go far toward creating the favorable tax climate that is essential to the stimulation of the mining industry in this country.

The economic device which has been proven successful in this country beyond the wildest dreams of the theorists, in raising our standard of living, has been free enterprise and the free market, with a minimum of imposed restrictions and limitations. It is the incentive of "profit" that makes the machine run, but the system is obviously one of "profit and loss"—not wholly profit, as its exponents know only too well. High mass-production; high wages for high productivity, permitting low unit costs; and the lowest price of product to consumers consistent with a fair unit profit; these factors constitute the formula that can yield maximum returns to individuals and to society in our free enterprise system. Wherever government steps in to control wages, costs, prices or any other factor, the results are negative.

The incentives necessary to maintain the mining industry at the high levels of output essential to our well-being as individuals and as a nation are the same sort of incentives that are essential to other businesses; opportunities for profit commensurate with the risks, and opportunities for achievement that are satisfying to venturesome spirits.

I am interested most of all in the youth of our country. I urge with all my heart that we may never close the doors of opportunity to our young men interested in the mineral industry, by stifling their initiative and ingenuity, their energy and courage, even their self respect, by offering paltry government "handouts" to the enterprises in which they may be engaged. Rather let us expand their opportunities a thousand-fold by reestablishing those natural and vital incentives which experience has long since proved to be effective in bringing our people to a position envied by every other people in the world.

Oxidized Lead Ore Recovered Profitably

by E. V. Given

IN speaking of the concentration of oxidized lead ores at St. Anthony, I do not wish to infer that we believe all lead ores of a similar grade can be mined and treated at a profit. Our oxidized ore is low grade, and certainly the mine under present economic conditions could not operate on this ore by itself. Because of favorable conditions we can operate the oxide circuit at a small profit although we do not allocate overhead, pumping, and certain other general charges to it. Operations in the oxidized zone were started as an essential part of the development necessary to outline and mine the sulphide ores.

Mr. Given is metallurgical superintendent for St. Anthony Mining & Development Co., Tiger, Ariz., and a member of AIME. **The paper was presented at the Arizona Section meeting, November, 1949.**

Nearly all of our oxidized lead ore comes from the Collins section of the mine, with the transition from oxide to sulphide ore lying between the 600 and 700-ft levels. Production from sulphide ore is much larger than from the oxide, both in tonnage handled and in grade of ore. The oxide and sulphide ores are never mixed either in the mine or the mill. The oxide mill sections have their own ore bins, grinding, and flotation departments. The lead minerals contained in the ore, in the order of their importance are cerussite, wulfenite, galena, anglesite, and vanadinite. The ratios of the different lead minerals change as the ore is pulled from different parts of the mine—total lead being approximately 50% to 60% cerussite, 20% wulfenite, 15% galena, zero to 10% anglesite, and 2% vanadinite. About 3% of the lead was unidentified.

The ore is ground in a 64½ Marcy ball mill in closed circuit with a Dorr rake classifier. Ore is ground to 44% minus 200 mesh, with classifier overflow being 25% solids. Although conditioning time is approximately 15 minutes, tests indicate that a smaller conditioner and less time would not alter results. Water is added to the conditioner and the 9 Denver flotation cells in sufficient amounts to reduce the solids to 20%.

Reagent setup is rather simple. Soda ash is added to the ball mill; reagent No. 425 and reagent No. 301 to the conditioner; aerofloat No. 31 and cresylic acid in a 50-50 mixture are fed to the first rougher cell, and sodium sulphide is added to rougher cells Nos. 1, 3, and 5. Soda ash is used in sufficient amounts to maintain a pH of 8.8 to 9.0 at the conditioner. Quantities of reagents No. 425 and 301 are set and are rarely moved except when tonnage factor changes. Sodium sulphide and the cresylic acid and aerofloat mixtures are the control reagents and it is necessary for the operators to do some juggling of these reagents to hold a steady froth.

4.367 pounds soda ash, 0.385 pounds reagent No. 425, 0.626 pounds reagent No. 301, 0.148 pounds aerofloat No. 31, 0.148 pounds cresylic acid, 1.780 pounds sodium sulphide. Reagent costs have been just under 50 cents per ton of ore.

The amount of sulphide minerals in the ore changes from time to time especially when ore is coming from near the transition zone in the mine. The galena floats readily, and no trouble has been experienced with its recovery, provided the circuit is not oversulphidized. Sulphide zinc, when present in amounts of 2% or more, is always detrimental. Not only does it lower grade of concentrate, but it is noted that lead recovery is nearly always lower if there is much sphalerite in the ore. Efforts to effectively depress this sphalerite have not been successful.

The fineness of flotation feed has been gradually reduced from 60% minus 200 mesh to 44% through 200 mesh. Difference in metallurgy due to a coarser grind is not noticeable. When we have had unusually high tailing assays, the largest loss, as a rule, is in the finer sizes. With a normal tailing of around 0.4% lead, assays are generally fairly evenly divided in the different screen sizes. Average screen analysis for the first ten months of 1949 are:

Mesh	Percent
plus 65	15.05
minus 65 plus 100	15.16
minus 100 plus 200	25.85
minus 200	43.94

The following figures are total production from start of oxide operations in late 1947 until October 31, 1949:

Table 1—Mill assays on oxide operation

	Dry Tons	Oz.Au	Oz.Ag	%Cu	%PB	%Zn
Heads	55,008.00	0.041	0.50	0.37	3.23	2.91
Concentrates	3,113.21	0.655	7.71	2.14	50.52	7.35
Tailing	51,894.79	0.004	0.07	0.26	0.39	2.65

Table 2—Mill recoveries in pct on oxide operation

	Au	Ag	Cu	Pb	Zn
Heads	100.00	100.00	100.00	100.00	100.00
Concentrates	90.12	86.56	32.94	88.55	14.28
Tailing	9.88	13.44	67.06	11.45	85.72

When considering that a great deal of this ore came from prospecting and development work, and that no extra employees were added to the mill crew to treat the ore, it is apparent that a rather sizable production has been made from a low tonnage and a low head ore.

A Classification and Application of Drill Jibs

For Rock Drill Mounting

The need for mechanized drilling to decrease mining costs has resulted in the development of the jumbo from column-and-bar drill carriages to hydraulically controlled jib jumbos. Resultant savings from use of improved jumbos have been high enough usually to retire the machinery investment within a year. The jib jumbo unit has been applied successfully to development and preparation programs and flat-bedded stopes, and an even wider field is forecast for its use.

by

O. J. Neslage

and

R. W. Jenkins

MINE operators today are paying increased attention to the mechanization of drilling operations as an important factor in increasing efficiency and decreasing costs. Recent progress in the design of drill jibs for mounting on drill carriages, or jumbos, has done much to advance the mechanization of mining methods. This progress has introduced new opportunities in the application of "jib jumbos" that are worth serious consideration. An attempt will be made here to classify the various types of jumbos and drill mountings available for level development and flat stope work, to indicate applications, and to measure their effectiveness in relation to their cost. The data here are based on a wide variety of field usage, and are offered only to point up, in a general way, the relative efficiency in proportion to cost. It should be remembered that any contemplated jumbo installation must be studied to determine what type of installation is most suitable, considering ground conditions, loading, timbering and haulage equipment, service available, and attitude of manpower.

O. J. NESLAGE and R. W. JENKINS, Members AIME, are Vice President Commercial Sales and Special Representative, respectively, Joy Manufacturing Co., Pittsburgh, Pa.

AIME Columbus Meeting, September 1949.

TP 2841 A. Discussion (2 copies) may be sent to Transactions *AIME before June 30, 1950. Manuscript received Aug. 26, 1949.*

Early Drill Carriages: The advantages of some sort of a drill carriage were recognized at the time rock drills were introduced. In drift or heading operations where a fairly standard drill round and cross section were anticipated, as well as in flat bedded deposits where standard slabbing rounds were used, track and crawler-mounted drills found an early application. These first drill jumbos were little more than drill carriers, designed locally and manufactured with materials at hand. Of comparatively simple construction, function, and low capital cost, they usually consisted of a hinged column which supported one or more drills on arms or universal bars. When the column was pivoted vertically, the drills were moved into position. Screw jack extensions reached from the column to the roof and floor to hold the drill rigid. In some cases, particularly in tunnel jumbos, enough weight was carried that rail clamps or roof jacks were sufficient.

Many of these column and arm-type jumbos, usually equipped with air and water manifolds, steel racks, and staging for drillers, are still in use today. Some have employed air or hydraulic extensions for securing the columns. They offer the time-saving advantage of having all the necessary equipment together, and they can be moved in and out, set up and torn down as a unit.

Boom-type Jumbos: When the advantages of the column-type jumbo were seen, operators began to realize the further gains possible. More time could be saved with mechanical assistance to position the drill vertically. A rack on the column and a pinion on the arm for raising and lowering the drill in the manner of a quarry bar were tried with some success. The most outstanding solution to the vertical handling problem was reached with the boom-type of jumbo. Here two or more machines were mounted on a cross arm at the end of a boom that was pivoted at the rear of the track. This was raised and lowered by various mechanical aids. Occasionally air or hydraulic power was used. Nearly all of today's wagon drills use this boom-type principle.

Fig. 1—Self-propelled, rubber tire-mounted "drill-mobile" with two hydrodrill jibs in a flat stope in a Missouri lead-zinc mine. Drills are 2¾-in. bore sinkers mounted on long feeds.

Boom jumbos represent a savings in time and physical effort expended in raising and lowering the drills. The boom must be balanced by the weight of the truck which is secured by rail clamps or roof jacks. The most successful application of this type of jumbo has been in the Tri-State area where multiple long-feed machines are used on caterpillar-mounted, boom-type jumbos for slabbing

This page of Transactions AIME is a continuation from p. 510. The missing pages appeared in Mining Engineering.

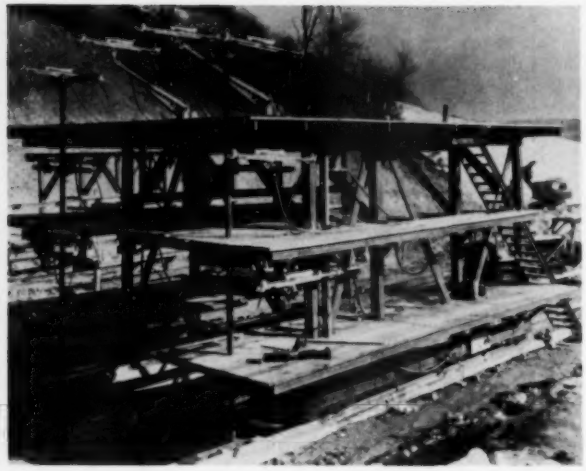


Fig. 2—Jumbo for a western Pennsylvania vehicular tunnel with hydrodrill jib mounting for top center drills to make high center holes easy to reach and to make possible rounding out the arched roof. Drills are 3½-in. drifters on 48-in. automatic feeds.

operations in large, flat stopes (fig. 1). Since the machines must be moved in and out horizontally on the cross arms by hand, they are best applied where rounds can be laid out with a minimum of lateral drill movement. In headings where the cross section is rectangular and the holes may be laid out in vertical rows, or where the "fanning" of holes can be tolerated, boom-type jumbos can be used effectively (fig. 2). The rounds used are the result of a compromise between the ground conditions and the limitations of the jumbo.

The greatest disadvantage of column and arm, boom-type jumbos lies in their lack of flexibility in arch or horseshoe section headings. Where "fanning" of holes resulted in overbreak and wall shattering and caused safety hazards, excessive timber support, dry packing, or "no pay" concrete filling was required. Moving the machines laterally had to be done by hand, wasting much time and physical effort.

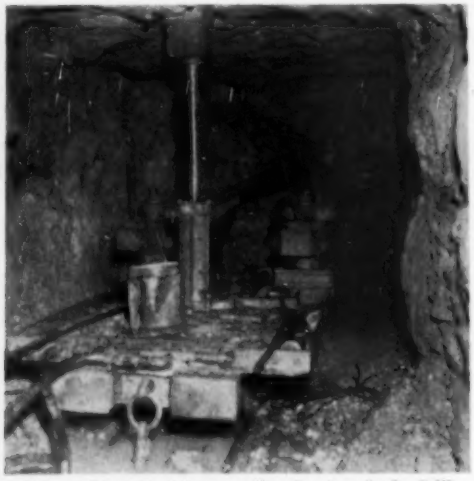


Fig. 3—Special wide mounting for two hydrodrill jibs in a wide drift in a Tennessee zinc mine. One miner drills and loads a 23-hole round in this large heading in a single shift.

Jib-type Jumbos: A drill support was needed which would allow the greatest flexibility in drill positioning and would effectively reduce idle time as well as excessive labor necessary to move the drill from hole to hole. The development of the jib-type met these requirements. It consisted of a single arm, free to swing in a horizontal plane. This arm was raised and lowered by a hand-operated screw jack, and could be locked horizontally and vertically. Although this jib was a tremendous improvement over previous mountings, it left much to be desired in rigidity, maintenance,

Fig. 4—Tunnel jumbo mounting 10 hydrodrill jibs with 3-in. on 36-in. feeds on a roadway tunnel job in the Hawaiian Islands.

and ease of operation. Vibration, corrosion, and the abrasive action of drill cuttings caused wear and looseness in the screw assembly which was reflected in excess drill maintenance and steel breakage.

The next step in jib development came from the coal mines where the same problems had been met with coal drills, universal tire-mounted cutters and mobile loaders. Problems there had been solved largely by the introduction of hydraulically powered equipment. It was a logical move to hydraulically operated jibs with the jib raised and lowered by a hydraulic cylinder which, for protection, is placed under the boom. Hydraulic pressure is applied by a hand-operated or air or electric-driven pump of simple construction. With this increase of available power, the arms can be made longer to cover greater face widths. The flexibility of the hydraulic system is further utilized by mounting swing cylinders on the jibs for positioning horizontally. All hydraulic cylinders are operated from the same pump by controls conveniently mounted on the jibs.

Advantages of Hydraulic Control: The superiority of hydraulic power was further evident from a safety standpoint. The cylinder supply pipes were designed so that if breakage occurred in the external

Table I. Classification of Jumbos, Other Than Wagon Drills

Type	Rigidity Secured by	Setting Up and Tearing Down	Positioning Machines	Example
Fixed col. and arm	Weight and anchor to rails	Swing arms ahead and raise on col.	Moving drills and arms by hand	Tunnel jumbos
Fixed col. and arm with mast	Weight and anchor to rails	Add mast and as above	Moving drills and arms by hand	ACM type
Pivoting col.	A. Weight and anchor to rails	Col. tipped vertically and secured		
	B. Screw jacks on cols.	Col. tipped ahead and screw jacks extended	Moving drills and arms by hand	Early Coeur d'Alene type
	C. Air-piston type cols.	As above except air bar extended	(1) Moving drills and arms by hand (2) Rack on col. and pinion on arm	Present Coeur d'Alene type Quarry-bar type
Boom type	Usually use rail clamps or roof jacks	Secure jumbo at face	Position machines vertically by raising or lowering boom. Move in and out on arms by hand.	Southwest type also Tri-State models
Jib type	Weight and hydraulic roof jack	A. Air hand-hydraulic roof jack, brakes on wheels	Jib is swung by hand. Raised by hydraulic cylinder on boom	Hydraulic jib
		B. Air hydraulic power on jack brake on wheels	Air or electric hydraulic raise and swing	Power-type hydraulic jib
	Hydraulic jack	Position and tighten jacks	Hand swing on booms. Hand-hydraulic vertical cylinder on cam	Screw-type jib
	Hand-screw jacks	Position and tighten jacks	A. Hand swing, hand screw on booms	Screw-type jib
			B. Hand swing, air-power screw on booms	Screw-type jib

piping, the jib could not fall so fast that the operator could not clear himself. This is a danger that is present in any screw-supported unit subject to high fatigue stresses from vibration.

Hydraulic jib mountings have been particularly successful in the elimination of overbreak. The ease and rapidity with which a miner may position his holes, allow him to drill rib and back holes parallel to the direction of advance and on the section line. Hydraulic jib units mounted on the top deck of tunnel jumbos to eliminate overbreak on the arch section have been extremely successful (fig. 3, 4, and 5).

The hydraulically operated drill jib provided a flexible yet stable support which effectively reduced the time and effort required to position drills. Since the weight of the drill was no longer an important factor, operators saw that other advantages could be gained by using a machine of sufficient feed length to drill the hole in one run. Numerous steel changes were no longer necessary. The rapid advances being made in the development of tungsten-carbide bits at this time answered the problem of too frequent bit changes. This new bit, along with small gauge, carbon-steel bits, made even greater penetration possible.

Long Feeds: The economy of long feeds is evident when one or more steel changes per hole are eliminated. Where a three or four change round can be drilled with only two changes, the savings in time and labor are apparent. The greatest economy is attained when the hole can be drilled without changing steels at all. In many cases, the tungsten-carbide bit or a small gauge, carbon-steel bit must be used to accomplish this.

The use of longer feeds offers many more advantages. The higher drilling speeds possible with smaller starting gauges are augmented by the elimination of steel changes. Less powder is consumed because it can be more evenly distributed throughout the nearly parallel walled hole. Greater blowing pressure in a smaller hole permits continuous operation, saving time and drill steels when drilling in broken or fitchery ground.

Because of the increased weight of the long feed drill, it must be used with either the jib- or boom-type jumbos. As previously mentioned, long feeds with boom jumbos have been successfully used in slabbing operations. Here, the machine does not have to be moved in and out on the arm. Jib mountings, however, are replacing booms even in slabbing operations.

Self-propelled Jumbos: A self-propelled, air-powered, pneumatic tired, dual or triple jib with long feeds for drilling 20-ft rooms is now available. In addition to power jib swing and power elevation, this unit can be equipped with extendable jib arms to maintain square room corners. Its close coupled, individually sprung wheels make it exceedingly maneuverable in narrow rooms and on rough floor. Other models include a small single jib unit for use in small section drifts in conjunction with slusher loading.

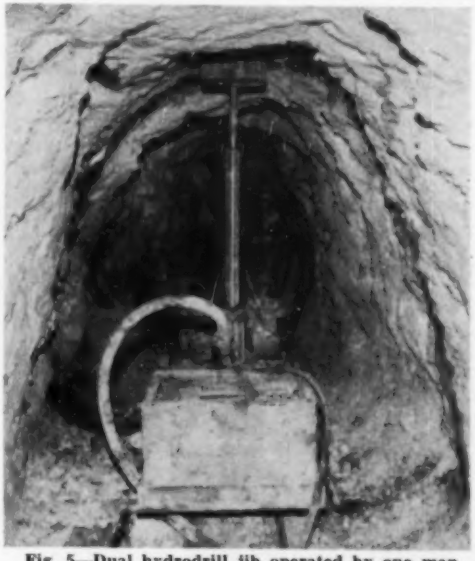


Fig. 5—Dual hydrodrill jib operated by one man in a 7x8 ft drift in a Montana lead-silver mine.

Table II. Comparative Efficiency, Labor Cost and First Cost of Various Type Jumbos Under Assumed Standard[a] Conditions

Description of Unit	Length of Feed, In.	Setup and Tear Down (Hr)	Drill Time (Hr)	Total Time (Hr)	Eff.[b] of Drilling, Pct	Adv. Ft per Man Hour	Labor Cost per Ft Adv.	Saving Over A per Ft	Saving[c] in 1 Year	Approx. Cost, Dollars
"A" Col. and arm less carriage	30	1.5	6.2	7.7	30	0.90	2.22			800
"B" Col. and arm on carriage		1.0	6.2	7.2	30	0.97	2.06	0.16	400	1,100
"C" Boom on carriage		0.75	4.2	4.95	40	1.4	1.43	0.79	1,970	1,500
"D" Hydrodrill jib		0.5	3.4	3.9	50	1.8	1.11	1.11	2,800	1,800
"E" Same with long feed	90	0.5	2.9	3.4	65	2.0	1.00	1.22	3,050	2,300
"F" Long feed and carbide bits		0.5	2.5	3.0	75	2.3	0.87	1.35	3,370	2,500

[a] Assumed conditions
1 man crew, 8x6 ft
Heading 24-7 ft holes
(168 ft drilling)
1.5 fpm drill speed
Labor $2.00 per hr.
Single drill used in all cases.
30 in. penetration, 30 in. feed carbon bits.
45 in. penetration, 90 in. feed carbon bits.
90 in. penetration, 90 in. feed carbide bits.

[b] Efficiency of drilling. Equal to:

$$\% = \frac{\text{Drill footage in ft (168 ft)}}{\text{Drill speed (1.5 fpm) x Drill time (min)}} \times 100$$

[c] 1 year's program assumed to be 2500 linear ft.

Classification: A classification of the various types of jumbos is shown in table I. Each type of jumbo is characterized, as described above, by the way in which rigidity is secured, how it is set up and torn down, and how the machines are mounted and positioned. An example is given for each jumbo type.

Table II is a chart which shows the comparative efficiency, as well as approximate labor and equipment costs, of various jumbo types. It shows, too, possible feed lengths, drilling times, and relative savings as based on more or less standard conditions as noted on the chart. It is necessary to present these figures in a general way, since there are a great number of variables between installations such as ground hardness, bit size, drill size, etc. All figures are derived from actual field conditions. Drilling efficiency here is assumed to be the ratio between "full throttle ahead" time to the overall drilling time including setup and drill-positioning time.

Savings with Jumbo Usage: Like other items of capital equipment, the initial price of refinements must be reflected in lowered operating costs in order to maintain a constant return on this investment. The increases in operating efficiency obtained with the various jumbos are excellent examples of improved returns as the capital investment is increased. Table II compares the various drilling units on bases of advance per man hour, drilling labor, cost per foot, capital price, and savings as compared to the lowest priced unit. An outstanding example is the case of the jib-jumbo units. Here, labor savings alone retire the capital investment in a year's program of 2500 linear ft.

Field experience in the use of jib-type units has verified these theoretical assumptions. A large western copper mine reduced contract labor costs from $2.75 and $3.35 per foot for 8x6 ft and 10x8 ft sections to $1.70 and $1.90 respectively. Another operator has maintained cost of jib-jumbo drifts at $5.00 per foot overall while the distance to the face has increased to 3000 ft. Ordinarily the price would have been increased to $6.50. Direct labor savings on jib-jumbo applications have run from $1.50 to $5.00 per foot. Advances per man shift of 4.67 ft in double headings and 3.6 ft in single headings of 9x7 ft cross section have been reported.

Applications of Jib Jumbos: All these savings are of course dependent on effectively using the time saved. Basically, if a machine is capable of saving a certain amount of money per foot of heading, the more it is used the more it will save. Utilizing this principle, many large operations have laid out their development and preparation programs to keep the jumbo constantly working on several headings rather than standing idle while mucking. One example of this program in a western mine is driving five headings, making three rounds on one shift and two on the other, using a dual jib jumbo and two shovel loaders. Weekly footage averaged between 150 to 180 ft in 10x9 ft headings. Three rounds could have been made on each shift except for delay in waiting for clean faces.

Another example of cost reduction by keeping a jib jumbo constantly at work is in bedded deposits where special drill crews on mobile drill units move from one heading to another. Loading and blasting are done by another crew. In this way, drill footage per machine shift has been doubled with no increase in labor.

Frequently, mine development must be done in single headings where the jumbo is idle during the mucking portion of the round cycle. Under these conditions, the higher drilling rate of the jumbo may be used to complete a longer round during the same cycle: the recent interest in burn cut rounds has developed techniques applicable to nearly all ground conditions for pulling to depths of 10 to 15 ft. Where ventilation and other safety precautions permit blasting during shifts, the jib jumbo is an effective means of increasing the number of rounds per shift in a single heading.

In closing, the hydraulic jib type is the most advanced of drill mountings and is the first unit to justify high production loading and transportation equipment for mine heading work. Its mechanical ability to support drills of all feed lengths and to ease the handling has been reflected in increased output per machine shift. To utilize properly this increased output, a thorough examination of every aspect of the work contemplated is necessary. Proper organization with planned service and cycling will increase advance and lower costs to a point where today's concept of cost on development work may be completely changed.

Production and Marketing of Garnet Abrasive Sands

From Emerald Creek, Benewah County, Idaho

Occurrence: small crystals in alluvial sands from the eroding Belt Series mica schists. Flowsheet: dragline, trommel screen, jigs, drier, crusher, screens. Value: ground, $2.50 per cu yd, garnet sand gross $60. per ton. Costs: production and sales $48. per ton. Uses: blasting sand in aircraft plants, monumental works, foundries. Efficiency comparison: superior to silica sand. Future: possibilities only touched upon, research continuing.

by John S. Crandall

THE mineral garnet, while ordinarily considered a semiprecious gem stone or a second-grade industrial gem, has also proved itself in the field of industrial abrasives. Its use is well known as a sandpaper grain, and as a sandblasting sand its qualities are rapidly becoming recognized in more and more industries.

Production of garnet as an abrasive is confined chiefly to two areas in the United States, North Creek, N. Y., where the Barton Mines Corp. operates, and Emerald Creek, Benewah County, Idaho, where the Garnet Mines, Inc., and the Idaho Garnet Abrasive Co. with mills at Fernwood, Idaho, operate.

JOHN S. CRANDALL is Manager, Idaho Garnet Abrasive Co., Spokane, Wash.

Third Annual Northwest Industrial Minerals Conference sponsored by the Columbia Section in cooperation with the Oregon and the North Pacific Sections, AIME, May 1949.

TP 2844 H. Discussion (2 copies) may be sent to Transactions *AIME before June 30, 1950. Manuscript received May 26, 1949.*

This paper is confined to a discussion of production and marketing of garnet sand by Idaho Garnet Abrasive Co.

Occurrence: Garnets in the Emerald Creek area occur as disseminated crystals in beds of micaceous schists of the Belt Series, which in this section are estimated to be close to 4000 ft thick. The schists are high in alumina and silica with iron, manganese, and magnesium. Subjection of the original sediments to high temperatures and pressures caused metamorphism to take place with the resultant recrystallization of high alumina-silica minerals such as garnet, mainly spessartite and almandite varieties, cyanite, sillimanite, chlorite, actinolite, tourmaline, biotite, and muscovite, with minor amounts of ilmenite and magnetite. Quartz is also present in considerable amounts.

Fast erosion of the soft mica schists on exposure to weathering has created extensive alluvial deposits containing up to 10 pct garnet having a maximum grain size of 3/16 in. These alluvial sands and gravels are now being treated for the recovery of garnet sands.

Treatment: Overburden of 1 to 4 ft must be stripped to expose the garnetiferous gravels. This operation and the subsequent feeding of the gravels to a trommel-screen washing plant are performed by a ¾ yd dragline. The trommel-screen openings are 3/16 in., thus allowing a separation and concentration based on grain size, since over 95 pct of total free garnets are minus 3/16 in. All plus 3/16-in. material is wasted at this point. The minus 3/16-in. material is further concentrated in a sand-drag classifier, where the slimes and silts are washed out and wasted. The sand product from the classifier varies in garnet content from 20 to 60 pct according to the particular section of ground being worked.

This sand product is trucked to a jig plant where two sized fractions are made in a trommel-screen. The minus 3/16-in. plus 10-mesh portion is fed to a Pan-American two cell 42-in. jig. The minus 10-mesh portion is treated in a Bendelari three cell 42-in. jig. The jig concentrates are combined to form a 98 pct garnet sand. The jig tailings contain 3 to 5 pct garnet which is mainly flat crystals and chips which will not settle into the jig hutch. Subsequent treatment of these tailings in a scavenger jig followed by drying and electromagnetic separation will, according to tests, reduce the garnet losses in the tailings to something around 1 pct.

Jig treatment of this feed approaches ideal as the major portion of the garnet crystals are the natural dodecahedrons and so are, in general, close to spherical. The specific gravity of pure garnet is 4.2, while the next heaviest mineral in the feed is cyanite with a specific gravity of 3.6, then quartz with specific gravity of 2.6. The garnet concentrate is practically free of quartz. The predominant impurity is cyanite which amounts to about 1.5 pct. The rod-like crystals of cyanite appear to up-end in the jig and go into the hutch with the garnets. Some ilmenite and magnetite appear in the concentrate but in very minor amounts. Subsequent washing in a sand-drag classifier removes fine silts and iron oxides.

The gravel feed to the washing plant will average 8 pct recoverable garnet content. Concentration ratio in this plant runs about 2.5 to 1. Washing-plant concentrate as fed to the jigs will average 45 pct garnet by weight. Concentration ratio of jigging runs about 2.2 to 1.

The garnet concentrate is dried in a rotary oil-fired drier and then fed to vibrating screens in closed circuit with crushing rolls.

Practically any grit from 10-mesh down to 150-mesh grain size may be graded to specifications in two 3-deck vibrating screens. The present production, however, is approximately 75 pct No. 36, 15 pct No. 60, and the balance No. 80 and No. 100. Metal-screen cloth is used for sizes down to 36 mesh. From 36 mesh and finer, silk-screen cloth is used since it has less tendency to blind.

All garnet sand is bagged in 100 lb self-sealing, sleeve-type paper bags. Practically all shipments are made in carload lots. Car loading is convenient since the plant is in Fernwood on the tracks of a branch line of the Milwaukee railroad. Truck shipments can and are made occasionally.

Values and Costs: The garnet content of the ground now being worked will average approximately $2.50 recoverable per yard, including overburden. The finished garnet sand loaded in the cars has a gross sale value of $60.00 per ton.

Production costs are all figured on garnet-sand product rather than on feed to any of the plants, and are as follows: stripping, washing, and trucking from the mine on Emerald Creek eight miles to the jig plant at Fernwood, $13.00 per ton of garnet sand. Treatment in the jig plant, $5.00 per ton of garnet. Treatment in the screening plant, bagging, and loading in cars, $10.00. A total of these costs is $28.00 per ton of finished product. This figure takes into account a 10 pct loss of sand due to the unavoidable generation of minus 100-mesh sand in crushing, which at the present time is being wasted because of lack of market.

A royalty of $3.00 per ton is paid on all garnet sand shipped from the plant thus bringing the total production cost to $31.00. Overhead, road maintenance, etc., along with a 20 pct sales discount bring the actual total production and sales cost to $48.00 per ton of finished garnet sand.

It is expected that mill improvements and changes made this spring will materially cut the production costs.

The screening plant has a present capacity of one to two tons per hour of operation, varying according to fineness of grits being produced.

Marketing: The Emerald Creek garnet has a hardness of 7.0 to 7.5 and has a typical gem-garnet color. A very few of the larger stones found in the area have been cut into ring and jewelry settings of considerable beauty and durability.

Tests and actual use of garnet sands in sand blasting show that the finer grits have a greater cutting efficiency than coarser sized, probably because of the greater number of cutting edges per unit of the sand. Crushed sand also has greater efficiency than the uncrushed sand of the same mesh sizes, probably because the cutting edges are actually sharper. The most efficient blasting sand appears to be a mixture of crushed fine and coarse grains, the maximum particle size being determined by the work to be performed.

Up to the present time all of the garnet sand produced in the Fernwood plant has been used as a sand-blasting abrasive. The principal users have been aircraft industries, both manufacturing and maintaining, U.S. Navy, U.S. Air Force, ship builders, monumental works, bronze, brass, and magnesium foundries. Garnet sand has also been used extensively to clean spark plugs in service stations, and for many other miscellaneous metal-cleaning jobs. Some glass designers have found the sand satisfactory as a material for etching and frosting.

Some experimental work has been done with marked success in glass and lens grinding where it is used as a secondary abrasive before polishing. Garnet sand with a fineness of minus 270 mesh has been tried as a denture polish in several dental laboratories and shows great possibilities. All of these latter uses require very fine material which must be very carefully and exactly graded to avoid scratching caused by oversize particles.

At present all material is graded in vibrating screens and with silk-screen cloth. The development of an appreciable market in the mesh sizes below 100 mesh will necessitate the use of air classification with the possibility of hydraulic classification in the very fine sizes, such as minus 325 mesh down to 700 mesh. Air classification would start at 65 mesh and would consist of a series of cyclones arranged in number and size according to the various grain-grading requirements of the market.

To date the market possibilities of Idaho garnets have just been scratched. Experimental work is being carried on by the Idaho Garnet Abrasive Co. and also by many users of the material. The following is a summary of the findings of one of such experiments performed by the Ryan Aeronautical Co. as a comparison of garnet sand and silica sand:

Direct cost:	Garnet grit	0.00536 cents per part
	Silica sand	0.00515 cents per part

The following advantages are not shown as direct material costs:

1. Smaller storage area required for garnet grit for the same number of working days.
2. Garnet grit will not draw moisture and may be used when wet.
3. Operator's vision is not obscured by dust.
4. The health hazard of silicosis is eliminated (where not cutting silica rock).
5. Replenishment of grit during operation is lowered 43 pct resulting in longer operating time.
6. Hauling charges and removal of residue is lowered approximately 50 pct.
7. 600 pounds of garnet grit is equal to 1400 pounds of silica in working efficiency.

An excerpt from a letter from the Glenn L. Martin-Nebraska Co. concerning comparative tests in their plant is as follows:

"Primary tests have shown this material to be about 2 or 3 to 1 ratio in usage, but we intend to run a more severe test and watch it very accurately with the laboratory in charge."

The results of these tests led to a 600 ton order for garnet sand.

The Battelle Memorial Institute, Columbus, Ohio, made a fairly complete comparative test on Idaho garnet sand in 1947 using grit sizes No. 24 and No. 60 against silica sand of the same mesh grades. The following is the conclusion made from these tests:

The most outstanding advantage shown for the garnet abrasive over silica sand is its greater cutting speed. The average cutting speed of the coarse garnet is about 30 pct greater than that of the coarse silica, and that of the finer garnet is about 50 pct faster than the finer silica.

The garnet also shows a marked advantage over silica in that more abrasive action is obtained per pound of abrasive consumed. This is chiefly the result of faster cutting with equivalent breakdown rates. This greater efficiency of the garnet abrasive is an important consideration with regard to cleaning costs for the two types of abrasive materials. Not to be overlooked is the possible reduction of the silicosis hazard with the use of garnet.

Conclusion: The production of garnet abrasive sand from the Emerald Creek deposits has been increasing with growing demands of the market. Better and more efficient methods of production and refinement are constantly being investigated and tried. Also the possibilities of broader markets are being explored.

With a high quality product such as these garnet sands, there will ultimately develop another stable and profitable production of nonmetallic industrial minerals from the Pacific Northwest.

Nonmetalliferous Mineral Resources in Arkansas

by W. B. Mather

Arkansas' nonmetalliferous deposits are of many different types. The principal types briefly described in this paper are: clays, shales and slates; silica deposits; limestone and dolomite; barite; gypsum; celestite; nepheline syenite; greensand; phosphate; vermiculite; fuller's earth; bentonite; diamonds; sand and gravel. The future development of these deposits is expected to effect profoundly the industrial development of the state.

ARKANSAS is not only a geologist's paradise, but it is also particularly fortunate in possessing a wide variety of mineral resources.

The future mineral production and mineral industry of Arkansas, like the other states in Mid-America, will probably depend to a large degree on efforts to increase the exploitation of the nonmetalliferous deposits of the state.

The term nonmetalliferous, as used in this paper, embraces all types of mineral deposits, except fuels, water, and those deposits from which, after beneficiation, metals are ultimately derived. For example, bauxite is the ore of aluminum, but a considerable portion of the bauxite mined eventually is employed in the production of nonmetallic alumina, an important oxide in the abrasive and ceramic industries. The bulk of the production, however, becomes metallic aluminum and therefore this type of mineral resource is considered metalliferous and is omitted from this paper.

W. B. MATHER, Member AIME, is Chairman, Division of Mineral Technology, Southwest Research Institute, San Antonio, Texas.

AIME San Francisco Meeting, February 1949.

TP 2845 H. Discussion (2 copies) may be sent to Transactions *AIME before June 30, 1950. Manuscript received Aug. 8, 1949.*

Arkansas' nonmetalliferous deposits are of many different types, too numerous to discuss in detail in a single paper; therefore, only their salient features are presented. Many types of deposits such as limestone, glass sand, novaculite, shale, and sandstone are exposed over wide areas, providing inexhaustible reserves. Other types of deposits, such as barite and tripoli, contain large reserves which certainly are not unlimited. Still other types of deposits, such as celestite, kaolin, and vermiculite, appear to occur in small isolated deposits containing relatively small reserves.

Of course, all of Arkansas' nonmetalliferous deposits probably have not as yet been recognized, nor have all of the known deposits been prospected, tested, and evaluated. Various types of deposits are too low grade or too limited in extent to be profitably produced by today's standards. In the case of other deposits, the known uses are few in number, thus acting as a retarder to their development. Due to anticipated technologic advancements, the future demands of industry are not expected always to be the same as they are today, and therefore idle deposits or those of current limited production may readily become the important revenue producers of the future.

The types of nonmetalliferous deposits discussed here include: clays, shales, and slates; silica deposits including glass sand, novaculite, tripoli, sandstone, chert, and quartz crystals; limestone and dolomite; barite; gypsum; celestite; nepheline syenite; greensand; phosphate; vermiculite; fuller's earth; bentonite; diamonds; sand, and gravel. The location of the various types of deposits are presented on the accompanying map (fig. 1). Symbols indicate the general area of occurrence. Many deposits, such as limestone, shale, novaculite, and so on, are represented by formations which could only be properly shown on a geological map. In these instances only active deposits or those of exceptional merit are indicated by symbols on the map. A general northeast-southwest line divides the interior highland from the Gulf Coastal and Mississippi Alluvial Plains of south and east Arkansas.

The data presented in this paper are only a summary of a portion of a more comprehensive survey and study of the natural resources of the entire state.[1] The study was sponsored and underwritten by the Arkansas Power and Light Co., Little Rock, as a public service to the state and its residents. Permission to present some of the data and conclusions resulting from the survey is gratefully acknowledged.

Table I, prepared by the Arkansas Geological Survey from state severance tax records, presents the annual production secured from Arkansas nonmetalliferous mineral deposits.

Clays, Shales, and Slates

Clays: It is realized that each method of classifying clays is prone to criticism. In this paper, Arkansas' clays of potential value are arbitrarily

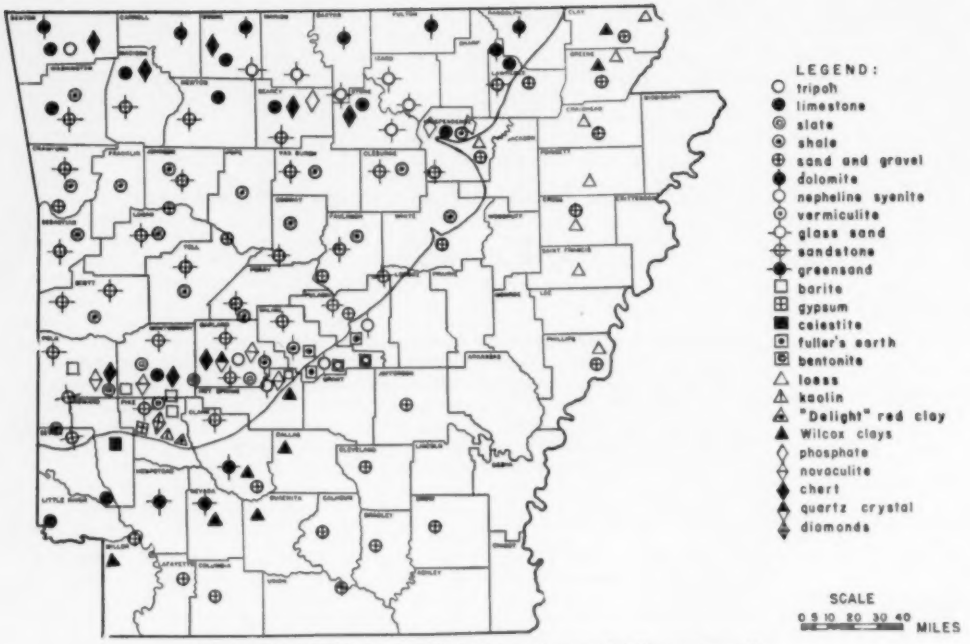


Fig. 1—Map of Arkansas with location of nonmetalliferous deposits.

NW-SE line separates interior highland and Gulf Coastal-Mississippi Plains.

divided on the basis of their position in the geologic column as follows:

1. Tokio clays of Cretaceous age exposed along the rim of the Gulf Coastal Plain in southwest Arkansas.

2. Wilcox clays of Tertiary age exposed along or a short distance from the edge of the Gulf Coastal Plain in south Arkansas and on Crowley's Ridge of east Arkansas. This group could also be extended to include Midway, Claiborne, and Jackson clays, but their value in the field of ceramics or industry in general is at present unknown.

3. Pleistocene loess, which forms a thick capping on Crowley's Ridge, is located in east Arkansas. It also occurs sporadically along the edge of the Mississippi Alluvial Plain of east Arkansas. Residual and transported clays of Recent age occur throughout the state.

The following brief discussion presents the salient features of the clays in each of these groups:

1. Two clays, kaolin and "Delight" red, belonging to the Tokio formation of Cretaceous age and located in Pike County, are believed to be the most important members of the first group of clays.

a. The kaolin (fig. 2), which is chalky white to cream-colored, distinctly bedded, flat-lying, 18 in. to 6 ft thick, has been described by Herold.[3] It is exposed in isolated deposits of limited extent on or near hilltops between the towns of Murfreesboro and Delight. Individual deposits contain up to 10,000 tons. Future prospecting should reveal new deposits now hidden by overburden. Its present use, as an additive in the manufacture of refractories, is sporadic. It has been shown to be a superior raw material for the manufacture of vitreous whiteware or any of the common uses of kaolin, such as a white filler in paper and rubber.

b. The "Delight" clay is a red, fine-grained, plastic, nonrefractory, transported clay, exposed in the vicinity of the town of Delight. The deposit is about 12 ft thick and is underlain by sand and overlain by 3 ft of gray clay. This clay has very high shrinkage and warping tendencies which are detrimental to its use by ceramic manufacturing industries, except in the case of terra sigillatas. Where color, plasticity,

Table I. Annual Production from Nonmetalliferous Mineral Deposits

Mineral	1947		1948	
	Quantity	Value	Quantity	Value
Barite, sh. tons	376,861	$2,411,910	362,403	$2,681,782
Cement, bbls	252,209	421,482	1,150,000	1,978,000
Chert roofing granules, sh. tons	20,762	160,690	27,686	214,290
Clay products[a]		1,437,839		1,620,599
Raw clay, sh. tons	249,639		332,090	
Glass sand, sh. tons	163,652	371,644	140,483	276,754
Gypsum, sh. tons	45,742	101,089	67,543	149,270
Limestone,[b] sh. tons	518,254	881,030	349,940	594,898
Novaculite (abrasive), lbs	1,350,880	135,088	368,000	36,800
Sand and gravel, sh. tons	3,356,355	2,882,566	3,188,252	2,773,779
Stone				
Dimension stone				
Limestone, sh. tons	880	40,550	3,707	170,818
Crushed stone				
Novaculite ballast, sh. tons	103,901	96,628	125,056	116,302
Sandstone, sh. tons	683,470	635,626	865,301	804,730
Syenite roofing granules,[c] sh. tons	107,289	1,582,508	158,756	2,341,621
Tripoli, sh. tons	900	17,091	1,800	34,182

[a] Includes brick, tile and other heavy clay products
[b] Chiefly agricultural and chemical grade limestone but includes some construction stone
[c] Artificially colored

Table II. Chemical Analyses of "Delight" Clay

	Delight Red[a]	Kaolin[a]
SiO_2	60.90	44.04
Al_2O_3	19.08	39.25
Fe_2O_3	7.20	0.68
CaO	0.20	0.26
MgO	1.41	0.21
Alk		0.13
TiO_2	1.13	
H_2O (140°)	1.00	
L.O.I. (1000°)		15.30

[a] Chemical analyses, unless otherwise specified, were made in our institute laboratories

and green strength are important, it may be used as an additive to ceramic bodies.

The chemical nature of these clays is revealed by the analyses given in table II.

The fusion point of the "Delight" red is between 2200°F and 2300°F, while that of the kaolin is cone 35 (3245°F). The latter is higher than most of the other kaolins in the country.

Fig. 2—Twin Knobs kaolin deposit near Murfreesboro, Ark.

2. The Wilcox clays of Tertiary age, recently described by Funnell,[4] may be subdivided into three principal types:

a. The first consists of ball-type clays, which normally exhibit the properties of white burning, refractoriness and plasticity; they are exposed in the vicinity of the town of Malvern near the east end of Magnet Cove in Hot Spring County and along the north portion of Crowley's Ridge. Present operators in the Malvern area have been mining clay from approximately a 300-acre tract. The thickness of the ball clay varies from 16 to 31 ft. Samples from several other undeveloped deposits in the area have also been tested. In addition to the present use of the clay as a blend in the manufacture of refractory brick and construction tile, it may be employed in the manufacture of chinaware, whiteware, and pottery bodies. The analyses in table III indicate the chemical composition of samples from two locations in the Malvern area.

This clay fuses between 2984°F and 3092°F.

Table III. Chemical Analyses of Clays in Malvern Area

	Acme	Malvern	
		Upper Gray	Lower Leafmold
SiO_2	61.30	58.06	59.52
Al_2O_3	24.94	27.55	24.95
Fe_2O_3	0.46	0.61	0.52
CaO	0.24	0.18	0.26
MgO	0.23	0.41	0.37
Alk	0.83		1.09
TiO_2	2.34	1.26	1.29
H_2O (140°)	0.62	1.08	1.00
L.O.I. (1000°)	8.12	8.76	10.97

b. The second type consists of sagger clays that normally exhibit refractoriness and plasticity. Arkansas sagger clays which are siliceous, refractory, and white burning are best exposed near Texarkana in Miller County and near Chidester in Ouachita County.

The following section is exposed in the Texarkana deposit (fig. 3):

4 to 6 ft—overburden
1 to 15 ft—white sagger clay
1 to 15 ft—yellow wad clay
base—lignitic blue clay and shale (Midway formation) suitable for manufacture of bloated lightweight aggregate

The Ouachita County deposit consists of alternating beds of white sagger clay, pure white sand, lignitic clay and is overlain by 18 in. to 2 ft of overburden. The white sagger clay beds vary from 4 to 8 ft thick (three beds).

These clays are suitable for the manufacture of sagger, pottery, flower pots, wall, floor and drain tile, stoneware and terra cotta, in addition to their present use as a blend in the manufacture of vitrified sewer pipe and white face brick.

The analyses in table IV present the chemical composition of these clays.

Table IV. Chemical Analyses of Sagger Clay

	Oneill Chidester	Dickey Texarkana
SiO_2	69.64	69.16
Al_2O_3	18.28	19.00
Fe_2O_3	0.43	0.56
CaO	0.22	0.12
MgO	0.43	0.45
Alk	2.18	1.59
TiO_2	1.33	0.88
H_2O (110°)	1.80	1.36
L.O.I. (1000°)	5.45	5.98

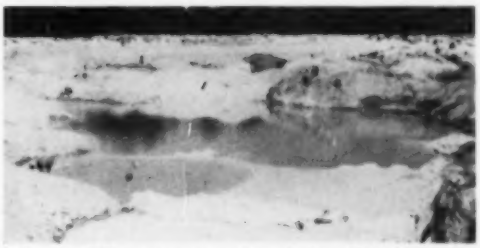


Fig. 3—Wilcox sagger and wad clay. Dickey clay pit north of Texarkana, Ark.

1. White sagger clay. 2. Yellow wad clay.

The fusion point lies between 2900°F and 3000°F.

c. The third type of Wilcox clay is a wad clay (actually low-grade fire clay) with plasticity its principal property. Arkansas wad clays are best exposed in the Texarkana deposit previously described, where 1 to 15 ft of yellow wad clay underlies the sagger clay. This material is used presently as a blend in the manufacture of vitrified sewer pipe but could also be employed as a wad between saggers or as a sealant for patchwork in kilns.

Other Tertiary clays belonging to the Midway, Claiborne, and Jackson formations, exposed in the Gulf Coastal Region and the Mississippi Alluvial

Plain of south and east Arkansas, should be included here; they are only mentioned, however, because sufficient time could not be allotted to their study. The dark Midway clay underlying the Texarkana Wilcox clays, for example, is a suitable raw material for the manufacture of bloated lightweight aggregate. Jackson clay, in the vicinity of Monticello has been employed as a bleaching clay, and elsewhere as raw material in the manufacture of brick and tile. Generalizations regarding these clays, however, cannot be made until they have been studied in more detail.

3. Loess (reaching a thickness of over 100 ft) caps Crowley's Ridge in northeast and east Arkansas. Small sporadic occurrences of loess are also located along the edge of the Mississippi Alluvial Plain of east Arkansas. During the early years of the present century loess was employed in the manufacture of brick at many locations along the Ridge—at Paragould, Blytheville, Forrest City and Helena, etc. Today the best opportunities offered for the development of these deposits lie in their employment as a raw material for the manufacture of bloated lightweight aggregate.

Residual and transported clays of Recent or Quaternary age derived from relatively recent erosion and sedimentation are found throughout the state. Many of these deposits are too small and too variable in composition to be of any known value. Red "tallow" clays, for example, developed through the weathering of Paleozoic limestones and dolomites, occur in small and often thin, sandy or cherty, erratic deposits. The "buckshot" clay of Quaternary age of central, south, and east Arkansas is extensive in area but highly variable in composition; in the early years of the present century, it was occasionally employed in the manufacture of brick. Thick beds of Quaternary red clay, along the Red River in Hempstead County of southwest Arkansas, have proved to be an excellent raw material for the manufacture of bloated lightweight aggregate. Pink colored clays, derived from the weathering of manganese-rich rocks and perhaps suitable as a pigment, occur in small deposits in the Batesville area. A detailed study of these and similar types of clays is a matter for future consideration.

Since the bauxite deposits were not studied during this survey, the accompanying kaolinitic clays were only examined in a cursory manner, and therefore are not discussed in this paper.

Shales: Paleozoic shales occupy a prominent position in the stratigraphic column of Arkansas. They range in stratigraphic position from phosphatic Cason of Ordovician age and black Chattanooga shales of Devonian-Mississippian age to the thick Atoka formation of Pennsylvanian age. The thickness of the various shale-bearing formations range from less than a foot to over 6000 ft (Stanley and Atoka). They are interstratified with sandstone, limestone, coal and novaculite beds and lenses. They occupy a large portion of the northwestern half of the state, in the Ozark Mountains, Arkansas River Valley, and in the Ouachita Mountain region. Their attitude ranges from vertical to horizontal, and their composition may vary from arenaceous and calcareous to phosphatic and carbonaceous. Various horizons have been used in the manufacture of brick and tile. Certain horizons in the Atoka formation are presently employed as a blend in the manufacture of vitrified sewer pipe. Other horizons, especially in the Moorefield and Atoka, have been found suitable for the manufacture of bloated lightweight aggregate. The phosphatic Cason and black carbonaceous Chattanooga, Fayetteville, and similar shales should be prospected as a possible source of uranium.

Slate: Shales of Ordovician, Silurian, Devonian, and Mississippian age, in the Ouachita Mountain region of central and west central Arkansas, have been converted into slates through the metamorphism which accompanied the mountain building of the area. These, of course, are highly contorted and are interbedded with sandstone and novaculite. They have been utilized in the manufacture of roofing shingles and at one locality (near Caddo Gap) are being used in the manufacture of roofing granules. Slates and shales of Saline County, locally converted into soapstone, were formerly mined for use as a lubricant. These deposits are available for any industry requiring a low grade form of talc, as in the production of foundry facing, insecticides, and possibly in the manufacture of roofing, paper, and paints, as well as in ceramics. Highly carbonaceous horizons should be checked to determine if they contain uranium.

Silica

Arkansas' silica deposits are divided into six types; glass sand, novaculite, tripoli, sandstone, chert, and quartz crystals. They have all been of some economic importance in the past, but it is anticipated that the greatest future development will probably be confined to the first three types of deposits.

Glass Sand: The St. Peter sandstone of Ordovician age is exposed over a wide area of the Ozark Mountain region of north central and northwest Arkansas.[4] It is a high-grade raw material similar to that of the St. Peter formation of central-east Missouri and the Oil Creek sand of east-central Oklahoma, both of which are major sources of sand for the glass industry of Mid-America. The only active glass-sand operation in Arkansas is located on the Missouri Pacific Railroad at Guion in Izard County. This operation is producing 10,000 to 20,000 tons per month by adit from the upper 55 ft of a 160-ft section of the St. Peter. The material is washed and sized at the mine. It is consumed by Arkansas' glass industry as well as that of adjoining states.

There are other formations in north Arkansas such as the King's River sandstone and the Calico Rock sandstone or basal member of the Everton formation, as well as unconsolidated sands of the Gulf Coastal Plain, that may provide suitable raw material for the glass industry, or any other requiring a high-grade raw material. One of the principal factors in the development of these deposits, in addition to grade, is accessibility to rail transportation. The quantity of St. Peter sandstone, easily accessible to railroad facilities, is inexhaustible; therefore, St. Peter sandstone will probably continue to be developed to the exclusion of the other potential glass-sand deposits of the state.

Novaculite: Arkansas novaculite, of Devonian age, is a cryptocrystalline, hard, flinty, white to black, siliceous rock. The tenacity of the rock apparently is not due to the cementing of the fine, angular quartz grains but rather to the interlocking of the grains. Novaculite crops out throughout the Ouachita Mountain area of central Arkansas, ex-

tending from Malvern west to near the Oklahoma boundary, and reaches a maximum thickness of about 950 ft. It is generally composed of three lithologic units: the lowest is massive, white novaculite; the middle consists of interstratified layers of black shale and thin-bedded dark novaculite; while the upper section consists principally of a massive, gray to white novaculite which in part is calcareous. The formation was highly folded during the development of the Ouachita Mountains, and therefore usually occurs in every attitude except horizontal. It is composed almost entirely of silica, as indicated by the chemical analyses[5] of table V.

Table V. Chemical Analyses of Novaculite

	White Novaculite, Hot Springs	Fine Ouachita	Ten Mile Quarry	
			White Ouachita	Black Ouachita
SiO_2	99.45	99.46	99.12	99.27
Al_2O_3		0.13	0.48	0.23
Fe_2O_3	0.26	0.06	0.02	0.03
CaO	0.12	0.04	0.12	0.06
MgO	Trace	0.08	0.06	0.08
K_2O	0.19	0.16	0.14	0.10
Na_2O	0.54	0.10	0.24	0.11
L.O.I.	0.06	0.14	0.22	0.60

Novaculite has been employed for a number of years as a raw material for the manufacture of whetstones and oilstones. For this purpose there are two classes of commercial material available in these deposits, the "Arkansas Stone" and "Ouachita Stone." Each class contains two types of stone, hard and soft. The Arkansas Stone is a very fine-grained, hard, compact rock which breaks with an uneven to conchoidal fracture, while the Ouachita Stone resembles unglazed porcelain and is relatively more porous. Pore space in the latter constitutes about 5.0 pct of the total bulk, as compared to 0.17 pct for the Arkansas Stone.

Novaculite is presently quarried at two locations in the Magnet Cove area as a raw material for the manufacture of silica brick and as a railroad ballast (Rock Island Railroad).

Loosely-consolidated Cretaceous conglomerates in Pike County contain thick accumulations of well-rounded novaculite pebbles. These have been found as suitable for use in pebble mills as the Danish pebbles currently imported at a price of 16 cents per pound.

Tripoli: Tripoli is the term usually applied to a cryptocrystalline white material composed almost entirely of silica. It is soft when mined, but cakes and case-hardens on exposure.

Arkansas has two types of tripoli, or at least tripoli of two different origins: (1) in Benton County of northwest Arkansas, tripoli reaches a thickness of 40 ft and is derived from chert; (2) in Hot Springs, Pike, Garland, and Montgomery[6] counties of central Arkansas, tripoli beds attain a thickness of 100 ft and are derived from novaculite.

The origin of tripoli is a matter of conjecture, but it is generally presumed to have been formed either by the action of ground water and normal weathering, or to have been deposited in its present form. Both these theories are inadequate in explaining Arkansas' deposits.

Tripoli, derived from chert, contains as high as 99.7 pct silica and as low as 0.018 pct iron oxide, while that derived from novaculite varies from 98.3 to 99.5 pct silica and from 0.19 to 0.40 pct iron oxide.

The open-pit mining of tripoli in the past has led to considerable contamination due to rain wash, etc. Future open-pit operators should try to avoid this source of contamination or, wherever possible, underground mining methods should be employed.

At present tripoli is mined northeast of Hot Springs (fig. 4) and processed at a plant in the city of Hot Springs. Two other mining and milling operations are expected to commence production in the immediate future in an area a few miles east of Rogers in northwest Arkansas.

The type of benefication process depends upon the market in which the tripoli is to be utilized. High-grade raw material may be secured in many instances by selective mining, while in other cases chemical treatment for the reduction of iron oxide is imperative. Where low and medium-grade raw material is required, simple drying, grinding, and sizing may be employed.

High-grade tripoli may be used by industry wherever a white color, fine particle size, high degree of purity and relative chemical inertness are of prime consideration. At present tripoli is used as an abrasive in scouring soaps and powders, metal polishes and in various metal-buffing compounds. It is widely employed in oil-well drilling mud and has also been used as a filler in paints, plastics, and paper.

Fig. 4—Tripoli deposit, Malvern Mineral Co., northeast of Hot Springs, Ark.

Arkansas tripoli deposits contain large reserves but they are not unlimited. The drilling of one deposit in Benton County has indicated an estimated reserve of between 1,300,000 and 1,800,000 short tons of tripoli.[7]

Sandstone: Under this heading all types of sandstone deposits are included, exclusive of sandstone employed by the glass-sand industry, which has been previously discussed.

Sandstone, of course, is a common constituent of the Paleozoic rocks in the northwest half of the state. It ranges in age from Ordovician to Pennsylvanian; in thickness, from beds of less than an inch thick to formations several thousand feet thick (Jackfork); in attitude, from vertical to horizontal; and in composition, from nearly 100 pct quartz grains to micaceous, calcareous, ferruginous, and argillaceous sandstones.

Partially consolidated to consolidated Cretaceous sandstones are exposed along the north and west edge of the Gulf Coastal Plain. They also vary in composition, often being marly. They are usually nearly horizontal in attitude.

Arkansas sandstones are employed entirely in building and road construction; however, the St. Peter sandstone of north Arkansas, in addition to its employment as a glass sand, has been used as a foundry sand.

Chert: Chert, more commonly known as flint, is a cryptocrystalline, hard siliceous rock, exhibiting a conchoidal fracture and usually is composed almost entirely of silica. It ranges in color from white (Boone) to black (Bigfork). It may also be reddish in color, due to iron staining, and black, due to manganese and iron. The two thickest and therefore most prominent cherts of Arkansas are: the gray to black Bigfork chert of Ordovician age, which is believed to reach a total maximum thickness of 700 ft, and occurs in the Ouachita Mountain area of central and west central Arkansas; and white cherty horizons in the Boone formation of Mississippian

Fig. 5—Limestone quarry, Batesville, Ark. St. Clair limestone block in foreground. Pink Fernvale limestone in quarry face.

age, which occasionally reach a continuous thickness of 50 to 60 ft in north Arkansas. Chert also occurs sporadically in many other Paleozoic formations.

The Boone chert currently is used as a road metal and could also be employed as a railroad ballast, while the Bigfork is used in the manufacture of roofing granules.

Quartz Crystals: Quartz crystals, of hydrothermal origin, have been mined for years from veins and cavities in sandstone formations of the highly folded Ouachita Mountain area of central and west central Arkansas,[8] especially in the area immediately north and west of Hot Springs. The crystals in the various deposits were investigated during World War II for their piezoelectric properties to determine their suitability for frequency control in radio receivers and transmitters. For the most part however the Arkansas quartz crystals are not adaptable for this purpose and therefore find their chief market as mineral collector's items, museum specimens, and also after cutting they are marketed by jewelry stores in Hot Springs under the trade name of "Hot Springs diamonds."

Limestones and Dolomites

Limestone: North and central Arkansas are underlain by Paleozoic formations, therefore, limestones are abundant, varying from Powell, Smithville, Everton, Joachim, Plattin, Kimmswick, and Fernvale of Ordovician age, through St. Clair of Silurian age to Boone and Pitkin of Mississippian age. The variety of limestone permits a wide variety of uses which are dependent on grade, color, texture, etc., ranging from the production of burned lime to road and building construction.

Noncherty portions of the Boone have been most widely used as the raw material for the manufacture of burned lime, although others, especially the Plattin, Fernvale, Kimmswick, St. Clair and Pitkin, with a calcium carbonate content of over 98.00 pct and in many cases in excess of 99.00 pct, are as suitable for this purpose or any other requiring a high-grade limestone.

In a state that is predominantly agricultural, large quantities of agricultural lime are required and all of these formations contain a sufficiently high-lime content to permit their use for this purpose.

Plattin, Kimmswick, Fernvale, and St. Clair in the Batesville area (fig. 5) are quarried for use as interior and exterior marble.

Siliceous black limestones of the Fayetteville and Pitkin formations have been widely utilized as a decorative stone. The "black marble" of the Fayetteville formation is a siliceous (silica content varies from 10 to 25 pct) limestone which derives its black color from included carbonaceous matter. The individual limestone beds, which vary in thickness from 1 in. to over 3 ft, are interstratified with black carbonaceous shale. The Pitkin limestone also contains carbonaceous zones that are called "black marble." These are usually of higher calcium carbonate content than those in the Fayetteville with correspondingly lower silica content (from 3 to 12 pct silica). "Black marble," in addition to its present use as a polished decorative stone, could be used successfully in terrazzo.

A sizeable mass of coarsely crystalline contact-metamorphic calcite crops out in the Magnet Cove area. It has been quarried for use as an "aglime."

Upper Cretaceous chalks occur along the north edge of the Gulf Coastal Plain in southwest Arkansas. Chalk of the Annona formation is believed to offer the best opportunities for development, as it reaches a thickness of over 150 ft and a central 55-ft section (fig. 6) contains 90.0 pct calcium carbonate. The farm land in the Gulf Coastal Plain of south Arkansas, as well as adjoining states, is "sour," requiring the addition of appreciable quantities of "aglime." These deposits of Annona chalk, which are suitably located along rail lines, should be producing "aglime" for the whole area. Arkansas' only cement plant, which is located at Saratoga, utilizes a portion of the Annona chalk as a raw material.

Impure limestones or marls of Tertiary age crop out along the Mississippi Embayment in Pulaski and Saline counties, but their low calcium carbonate content (47 to 76 pct) more or less limits their potential use to the manufacture of rock wool.

Dolomite: Dolomite in Arkansas is restricted principally to outcrops of Jefferson City and Cotter formations along or adjacent to the Missouri boundary in northwest and north central Arkansas. These dolomites are often very high grade and at one location are produced as a raw material for the Oklahoma glass industry. In certain localities they could be employed as a source of burned magnesia and almost everywhere as a source of "aglime."

Barite

Since 1945 Arkansas has been the nation's principal barite producer. The output is employed almost entirely in the manufacture of drilling mud. Arkansas barite occurs as a replacement deposit at the base of the highly folded Stanley shale, immediately overlying the Arkansas novaculite. Barite apparently replaced carbonate-rich zones in the shale, leaving thin intercalated sandstone beds unaltered. It also has been found as a replacement deposit in

the upper portion of the novaculite formation, occasionally replacing the novaculite.

Two companies, National Lead Co. and Magnet Cove Barium Corp., are mining barite from a synclinal structure northeast of Magnet Cove. The baritic zone is 35 to 45 ft thick and mine dirt averages about 67 pct $BaSO_4$.[9] Both open-pit and underground mining methods are employed. The ore is beneficiated by flotation, producing a 92 to 95 pct product. The estimated reserve as of January 1949 in this deposit was 8,400,000 short tons.

Similar type barite deposits have been prospected in Montgomery, Polk and Pike counties.[10] The Montgomery County barite deposits, which are located some 40 miles west of Hot Springs, have been described by McElwaine.[11] The Gap Mountain deposit is composed of four lenticular barite bodies, 300 to 1200 ft in length, 20 to 30 ft thick, with a vertical to steep dip. The Fancy Hill deposit is composed of six lenticular deposits, 300 to 1800 ft long, 30 ft thick, with nearly vertical dip. The Sulphur Mountain deposit, which is located along the opposite limb of the syncline to the Fancy Hill, has not been as extensively prospected, but it is known to have a minimum thickness of 26 ft, and a minimum length of 250 ft and a dip of 50°. The U. S. Bureau of Mines has drilled and sampled these deposits.[12]

The estimated barite reserves for the entire state of Arkansas, as of January 1949, were 15,000,000 short tons of +40 pct ore.[13]

Structural and stratigraphic conditions exhibited by the known barite occurrences extend from Magnet Cove to Mena near the Oklahoma border; therefore the possibilities of finding new deposits in this 100-mile stretch appear favorable.

Gypsum

Gypsum occurs in south Pike County in the DeQueen member of the Trinity formation (Lower Cretaceous). The gypsum is white to pinkish in color, fine-grained and massive. Veins of satin spar are abundant. The principal bed is relatively flat-lying and averages about 7 ft in thickness with a maximum thickness of 12 ft. It usually contains a 1-ft bed of black shale 3 ft from the base.

The gypsum was formerly mined by underground methods, but today open-pit mining methods are employed, requiring the removal of some 30 ft of overburden. Present production from the one active operation at Highland averages about four cars per day. It is consumed entirely by the cement industry. A much larger production could be secured if the present operators were permitted to extend their market.

Celestite

Celestite or strontium sulphate was mined in Howard County during the last war and, like gypsum, occurs in the lower part of the DeQueen member of the Trinity formation. The celestite is found in pink, to gray, coarse-grained masses which are easily broken. It occurs in a flat-lying bed and varies in thickness from 1 in. to 1 ft. It appears to underlie the top soil of treeless portions of otherwise heavily forested areas, the soil being unable to support trees. The thin character of the known beds limits the use of the material (pyrotechnics) to a period of national emergency.

Nepheline Syenite

Nepheline syenite crops out in the Little Rock, Benton, and Magnet Cove areas of central Arkansas. The lateritic weathering of this rock produced bauxite in the two former areas. It is currently employed in the manufacture of roofing granules at the Little Rock plant of the Minnesota Mining and Manufacturing Co. It has also been used as a building stone and as an aggregate in construction work.

The Arkansas Geological Survey,[14] in conjunction with the Rolla Branch of the U. S. Bureau of Mines, has been conducting laboratory tests with nepheline syenite on the separation of the nepheline and feldspar from the iron-bearing minerals. The separation of these components was successful, but the cost of the process is too high to permit the present employment of the material as a flux by the ceramic industry. It is hoped, however, that through future technologic developments, Arkansas nepheline syenite may some day become an important raw material in the ceramic industry.

Fig. 6—Annona chalk at White Cliffs, Ark.

Greensand

Greensand or glauconitic-bearing sand and marl crop out in thick beds of upper Cretaceous age (Nacatoch Sand) in Hempstead, Nevada and Clark counties. East of the town of Washington, in Hempstead County, the greensand bed is more than 50 ft thick. The potash content, which varies from 1 to 4 pct, is too low to permit the production of this material by either the water softener or fertilizer industry. The deposits, however, require further prospecting and evaluation.

Phosphate

A nodular phosphatic zone in the Cason shale, reaching a maximum thickness of 6 ft, extends across several counties of north Arkansas. Sampling reveals a phosphate content of about 30 pct P_2O_5. These deposits have not been able to compete on the open market with Tennessee and Florida phosphate; however, future prospecting may discover thicker and richer phosphatic beds in this shale. In addition, future tests on the application of ground rock phosphate directly to the soil may provide a large local market for this material. The knowledge that phosphatic shales occasionally possess a uranium content should lead to a thorough prospecting of these Cason shale exposures.

Vermiculite

Vermiculite is derived from the weathering of ouachitite sills and dikes in Hot Springs and Garland counties of central Arkansas. The depth of the weathering is unknown and therefore the extent of the deposits is a matter of conjecture. The ouachitite, originally consisting of biotite and augite pheno-

crysts in a glassy to fine-grained ground mass, has been decomposed through weathering to a clay containing altered biotite crystals. The latter, which have been converted to vermiculite, reach a maximum width of 1 in. The sills provide the best prospect of future production of this insulating material, if they are of sufficient thickness and if weathering has been sufficiently extensive in area.

Fuller's Earth

Fuller's earth or bleaching clay, which is used in the decolorizing of oils, occurs in several central and southern Arkansas counties. It has been reported in Saline, Drew, Pulaski, Searcy, Ouachita, Grant, and Dallas counties. It occurs as a transported clay, as for example the Tertiary deposits in the Jackson formation near Monticello, Drew County, and as a residual clay, formed by the weathering of basic igneous dikes, as at Olsen Switch in Saline County.[15] The latter has been the site of most of Arkansas' production, which was sporadic from 1901 to about 1940. Between 1904 and 1907 Arkansas ranked second nationally in the production of fuller's earth and third from 1909 to 1911, inclusive.

Bentonite

Bentonitic clays, derived from the weathering of volcanic ash, have been reported in Saline, Hot Springs and Grant counties. True bentonite possesses the property of absorbing several times its volume of water. To date, this type of material has not been found in the state and, although the deposits are locally called bentonite, they actually belong to the class of clays known as metabentonites or nonswelling bentonites. While the former, due to its absorptive properties, is employed in drilling muds and the grouting of dams and drainage ditches, the latter is often employed as a lubricant and, because of its base exchange properties, is used in the water-softening industry. Two of the four deposits in Saline County and one in Hot Springs County produced a total of 3988 short tons between 1933 and 1938.

Sand and Gravel

Sand: Sand, suitable for all types of construction, occurs in inexhaustible quantities throughout most of the state. In the area underlain by Paleozoic formations it is derived from the weathering of sandstones. In the remainder of the state, or in the Gulf Coastal and Mississippi Alluvial Plain, Tertiary and Recent sand deposits are abundant. In several localities, as at Fort Smith, Little Rock, Dardanelle, and Newport, it is secured from river channels. The principal consumer is the construction industry, although it has been reported that some production in the past has been utilized by the glass industry.

Gravel: Gravel, like sand in the northwest half of the state, is produced by the disintegration of Paleozoic rocks. In the Gulf Coastal Plain of south Arkansas and Mississippi Alluvial Plain of east Arkansas it occurs in Cretaceous conglomerates and in Quaternary terrace deposits. The Quaternary gravel deposits underlying the loess deposits of Crowley's Ridge, in the latter area, are probably the most uniform, and in the past have been the most widely used deposits in the state.

Diamonds

A discussion of Arkansas' nonmetalliferous mineral resources would not be complete if the Arkansas diamond deposits were omitted. These are the only known diamond deposits on the continent. They have been inactive for some time but at present are being reopened. In the past, the diamonds were mined from the residuum derived from the weathering of three volcanic plugs near the town of Murfreesboro, Pike County. Although 8 to 10 pct of the yield are reported to have been of gem quality, the deposits were never successfully exploited as a source of gem stones. It may be a matter of interest to note that the largest diamond found in these deposits, known as the "Uncle Sam," weighed 40.23 carats and was cut to a 14.3 carat gem stone. If the deposits are to be reopened, it appears that it will be necessary to concentrate on the production of industrial stones rather than those of gem variety.

Conclusions

This concludes a brief résumé of Arkansas principal nonmetalliferous mineral resources. The industrial potential, lying dormant in these deposits, is believed to be extensive. The wide variety of deposits predicates their future employment by a wide variety of industries. The development and production of nonmetalliferous deposits are not wrapped in the legend and romance of metalliferous deposits and their production and beneficiation usually produce a relatively low-priced raw material; however, the often unlimited reserves and relative ease of processing provide a long life, relatively low initial investment and the employment of fewer highly trained technical personnel for anyone contemplating entering this field.

References

[1] G. W. Ward, W. B. Mather, J. E. Funnell and Noel H. Wood: Natural Resources of the State of Arkansas. Ark. Power and Light Co., Little Rock. (1949).

[2] Paul G. Herold and George R. Heyl: Kaolin Deposits of Southern Pike County, Arkansas. Ark. Geol. Survey. *Bull.* 7 (1942).

[3] J. E. Funnell: Recent Studies of Wilcox Group Clays in Arkansas. Accepted for publication in the *Bull.* Amer. Cer. Soc.

[4] Albert W. Giles: St. Peter and Older Ordovician Sandstones of Northern Arkansas. Ark. Geol. Survey. *Bull.* 4 (1930).

[5] Staff, Ark. Geol. Survey: Mineral Resources of Montgomery, Garland, Saline and Pulaski Counties, Arkansas. County Mineral Rept. No. 3 (1942) 67.

[6] Robert B. McElwaine: Two Tripoli Deposits in Pike and Montgomery Counties, Arkansas. Private Publication, Little Rock. (Sept. 20, 1948).

[7] J. Norman Payne: Univ. of Ark. Personal communication.

[8] Hugh D. Miser: Quartz Veins in the Ouachita Mountains of Arkansas and Oklahoma (Their Relations to Structure, Metamorphism, and Metalliferous Deposits). *Econ. Geol.* (1943) **38**, 91-118.

[9] T. A. Jones: Barite Deposits in the Ouachita Mountains, Montgomery, Polk and Pike Counties, Arkansas. U.S. Bur. Mines. *R.I.* 4348 (1948) 1.

[10] Op cit.

[11] R. E. McElwaine: Exploration of Barite Deposits in Montgomery County, Arkansas. U.S. Bur. Mines. *R.I.* 3971 (1946).

[12] Op cit.

[13] H. B. Foxhall, State Geologist: Personal communication.

[14] W. E. Crockett and H. B. Foxhall: Preliminary Report of Occurrence and Properties of Nepheline Syenite in Arkansas. Cer. Soc. *Bull.* (1948) **27** (2) 64-67.

[15] Op cit: 56-59.

The Burt Filter

by W. G. Woolf and A. Y. Bethune

Filtration of hot (60°C) supersaturated zinc sulphate solution (sp gr 1.540) from slimy leach residues at the electrolytic zinc plant of Sullivan Mining Co., Kellogg, Idaho, is described. Separation of liquids and solids in the finished leach is by Burt filters modified to meet conditions of high-acid, high-density process for electrolytic zinc. Operating characteristics of the Burt filter on this pulp are presented.

THE hydrometallurgy of special high-grade zinc as practiced by the Sullivan Mining Co. at its electrolytic zinc plant, Kellogg, Idaho, involves an important filtration step immediately following the leaching process. By means of the filtration the heavy zinc sulphate solution is separated from the residual products which remain after the zinc calcine has been dissolved in the sulphuric acid electrolyte. Because this plant uses the so-called high-acid, high-density process[1] for the production of superpurity zinc metal the above mentioned filtration must be accomplished in the face of certain difficult conditions inherent in the process.

[1] W. G. Woolf and E. R. Crutcher: Electrolytic Zinc Plant, Sullivan Mining Company. *Trans.* AIME (1936) 121.

W. G. WOOLF and A. Y. BETHUNE, Members AIME, are Superintendent and Assistant Superintendent, respectively, of Sullivan Mining Co., Electrolytic Zinc Plant, Kellogg, Idaho.

AIME San Francisco Meeting, February 1949.

TP 2770 B. Discussion (2 copies) may be sent to Transactions *AIME before June 30, 1950. Manuscript received Nov. 15, 1948; revision received Oct. 18, 1949.*

First, the strength of the electrolyte (270g H_2SO_4 per liter) results in a saturated zinc sulphate solution, having a specific gravity of 1.510 to 1.540, which must be kept warm during filtration because of its property of "seeding out" small crystals if allowed to drop much below 60°C. Second, the action of the "high" acid on zinc calcine under the temperature conditions of the leach (80° to 102°C), although favorable to good zinc extraction, causes a considerable quantity of iron to be dissolved (8 to 18 g per liter) along with variable quantities of alumina and silica, depending on the grade and type of original zinc concentrates roasted. These three, iron, alumina, and silica, are almost completely precipitated during the neutralization of the leach (only a few milligrams per liter of each remain in solution), so that the resulting pulp, instead of being a granular, sand-like product having a particle-size distribution dependent on the fineness of the zinc calcines leached, is in reality a slimy, chemical precipitate whose filtration characteristics constantly change depending on the amounts of iron silica, and other impurities, which are dissolved and reprecipitated. Third, the combination of supersaturated solution of high specific gravity plus a dense, semigelatinous residue creates a difficult washing problem requiring a positive displacement wash to liberate the zinc sulphate entrapped in the pulp.

In a closed-cycle hydrometallurgical operation, such as practiced in this plant, the extent of washing is determined by the volume limitations imposed on the intermediate wash waters by the amount of "fresh" (or process) water which may be added. The volume of fresh water used for make-up purposes is limited to the amount which is lost during the closed cycle by evaporation in the leach, sulphate content of the calcines leached, moisture content of the residue, and spillage.

The Burt filter as modified and improved by the Sullivan Mining Co. has successfully met and overcome these difficulties under a variety of zinc plant operating conditions since 1928. It might have many interesting applications to metallurgical fields other than that of electrolytic zinc, and its possible usefulness to hydrometallurgists in general warrants its description and discussion.

The Burt filter is so named from its inventor who originated it in Mexico for pulp filtration in the cyanide process for gold and silver ores. While retaining the basic principle of Burt's earlier revolving pressure-type filter with internal filtration media, a number of modifications and improvements have been made in Sullivan Mining Co.'s installation.

The Burt filter may be classified as a batch-type pressure filter in contradistinction to either the conventional vacuum-type filter, which depends on atmospheric pressure to force solution through a cloth medium, or to the filter-press, which employs whatever pressure is imparted by the pump delivering the liquid being filtered. The Burt consists essentially of a hollow steel cylinder about 40 ft long, 5 ft in diameter, resting horizontally, and capable of rotation about its long axis. It is supported on one end by a hollow trunnion and near the other end by a riding-ring and roller combination. The cylinder is lined with filter units each fastened against the inside of the shell and parallel to the long axis so as to form a hollow cavity into which pulp may be charged. A specific amount of pulp is admitted to the filter and a unique valving arrangement prevents the loss of pulp while air pressure forces the solution through a canvas medium to the discharge port of each filter unit. The residue is left on the surface of the canvas inside the cavity. The remainder of the filter cycle is concerned with washing the residue free of zinc sulphate, discharging it from the Burt, and preparing the filter for the next charge.

A more detailed description of Burt filter construction, a typical filter cycle, and its operating characteristics when employed on material encountered in this plant will be given in that order.

Description of the Filter: Fig. 1 shows a side elevation view of a filter with riveted shell construction. Since this drawing was made shells have been fabricated by welding, instead of riveting, with complete success. Shells are lagged on the outside to retain heat. Fig. 1 shows a side elevation and plan view of a Burt filter in operating position. The ½-in. steel shells are lined with 3/16-in. copper sheet as protection against the corrosive action of the solution (containing about 500 mg Cu per liter) on iron, and the copper is given a thin protective coating of plastic-base paint. Fig. 2 is a view from the discharge end of the filter, with head removed, before filter units are fastened to the periphery. It shows

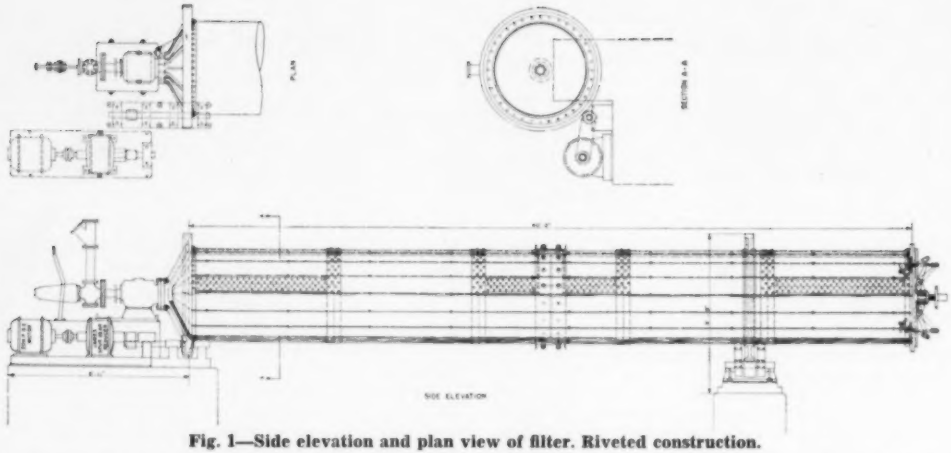


Fig. 1—Side elevation and plan view of filter. Riveted construction.

the copper lining in place and the interior of the filter.

The individual filter units, called "boards," are made of wood. They consist of a solid core overlain with two grooved surfaces, each 12 in. wide, which collect the filtered solution and channel it toward the discharge port located at one end. The assembled board is 19 ft 7½ in. long, triangular in cross section, with a 33° internal angle between the grooved surfaces. The surface grooves are ¼ in. deep by ¼ in. wide. The entire board is covered with a specially manufactured canvas "sock" or bag of "palmatwill" weave, the open end of which is folded over, then sewn tightly with linen thread to prevent leakage of any solids through to the grooved surfaces.

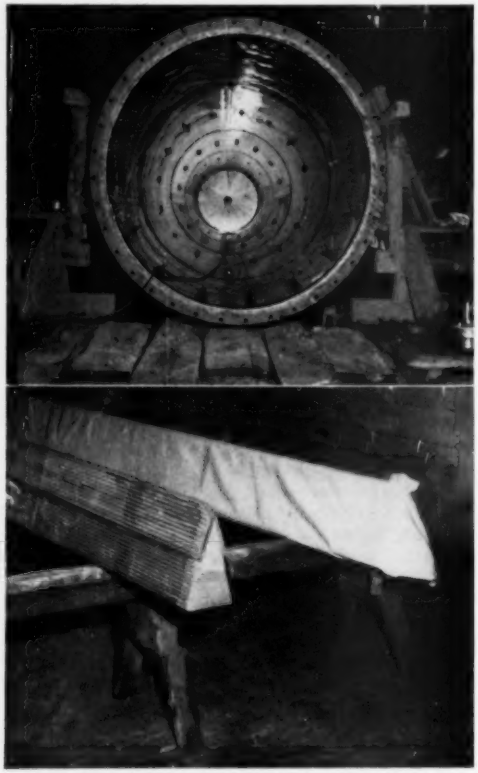


Fig. 2—Interior of filter from discharge end, before installation of filter units.

Fig. 3—Showing discharge nipple and individual filter boards before and after covering with canvas.

Fig. 3 shows the individual filter boards before and after covering with canvas. Fig. 4 gives various views of a board and shows the manner of its attachment to the inside of a filter.

The third side of each board acts as the base of the filter unit and is fitted at midpoint with a bolt which protrudes through the shell and holds the unit firmly against the copper lining. A hollow solution discharge nipple at one end of the board secures the unit at the center of the filter, while specially designed wing-washers or lugs anchor it at the opposite end. Fig. 5 shows a filter with all units installed, and the wing-washers holding them in place.

Thirty-two units, or boards, constitute a full set for one Burt filter. Each unit has an effective filtration area, calculated from the dimensions of the two grooved surfaces on which the canvas rests, of 37.046 sq ft. Total filtration area is 1185.5 sq ft.

The feed inlet valve mechanism and the supporting trunnion at the head-end of the filter is shown in fig. 6. The essential features are the hollow charge pipe leading to the interior of the filter, the "flapper-valve" which seats on the end of the pipe, inside the filter, the hollow rod which activates the flapper, and the stuffing chamber. Through this hollow charge pipe all pulp and all subsequent washes are admitted to the filter. They are prevented from escaping under pressure by the flapper-valve which seats against the pipe when pulled shut by the hollow rod. Through the hollow rod, high-pressure air is applied to the filter. The stuffing chamber allows movement of the rod back and forth when necessary, and permits rotation of the filter without loss of air pressure. Various admittances to the filter, and even the application of vacuum, are controlled by individual valves on the separate lines. Fig. 7 gives a general view of the head end of a filter showing the separate pipelines and valves for the various washes, air vacuum, and steam.

The mechanism at the discharge end of the filter

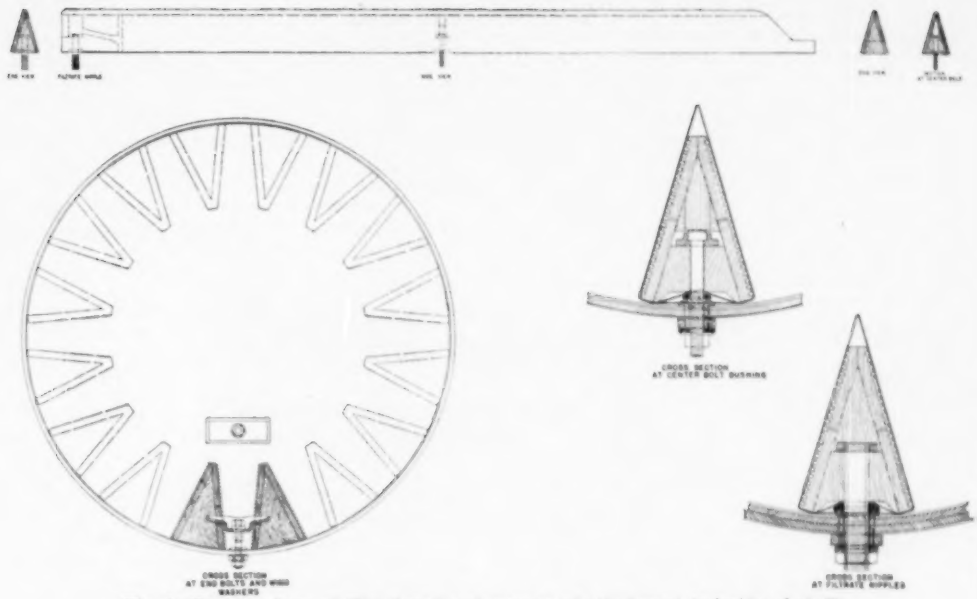


Fig. 4—Various views of filter board and manner of attachment to inside of shell.

is shown in fig. 8. The discharge ports are activated by a simple screw device, manually operated. The ports seat on the inside of the filter and are faced with live rubber. Turning the wheel clockwise closes the ports; counterclockwise opens them.

An ordinary hand valve placed near the outer edge of the discharge head acts as a relief valve to eliminate back pressure when the filter is loading, and as an indicator to show when it is fully charged.

Filter Cycle: Before describing a complete filter cycle it must be pointed out that the time consumed per cycle, and the results obtained, will depend almost entirely on the character of the pulp in question. Different mechanical setups may affect overall cycle times somewhat, especially in regard to charging and discharging, but, in the main, the ease or difficulty with which certain pulps filter and wash will determine the entire operation.

A complete cycle will involve the following: (1) charging (with leach pulp); (2) filtration (production of "Burt" solution); (3) first wash (with "weak" wash); (4) second wash (with "weak" wash); (5) third wash (with "mull" water)*; (6) repulping (with mull water, plus vacuum); (7) discharging (production of zinc plant residue); (8) flushing (with mull water); and (9) blowing closed filter (with air).

* "Mull" water is the term applied to the most dilute solution used on the filters. It consists essentially of process water (well water, condensate, any "fresh" water) plus small quantities of zinc sulphate leached from the zinc plant residue in the thickener operation. Any volume loss in the mull water circuit is made up by adding process water.

A typical cycle is as follows:

(1) The filter, blown dry, is set for maximum loading by spotting the relief valve on the discharge head to upper dead-center position. The flapper valve is opened, and leach pulp is charged to the filter, by gravity flow from a storage tank, through a separate line suitably valved for that purpose. The operator opens the relief valve and waits until the cessation of escaping air and the appearance of leach pulp indicates the filter is fully loaded. Time of loading is about 15 min. Theoretically the filter has a capacity of 17.29 vt* (4144 gal or 553.9 cu ft).

* The volume unit, (abbreviated vt), used in this paper refers to one volume ton, which is the volume occupied by 1 ton (2000 lb avdp) of water at 4°C. It is equal to 239.69 U.S. gal. The specific gravities are referred to water. The heavy solutions are usually tested at 60°C.

All valves are then closed and air pressure of 40 lb per sq in. is applied. The filter is caused to rotate. Rotation continues throughout the entire cycle, until the filter is again spotted for discharging.

(2) Filtration proceeds for about 45 min or 1 hr with Burt solution at a sp gr = 1.540 (60°C) being discharged at the center of the filter, collected in a sump located under the filter and pumped to storage tanks. When the major portion of the Burt solution has been filtered away from the residue, the cake, adhering to the filter cloth, "cracks." This allows the escape of warm, moisture-laden vapor, through the solution discharge nipples thereby creating a

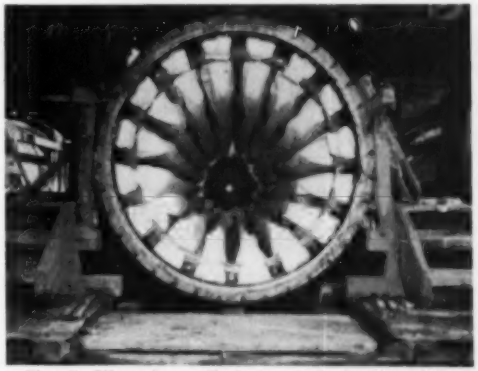


Fig. 5—View from discharge end showing filter units installed and held in place by wing-washers.

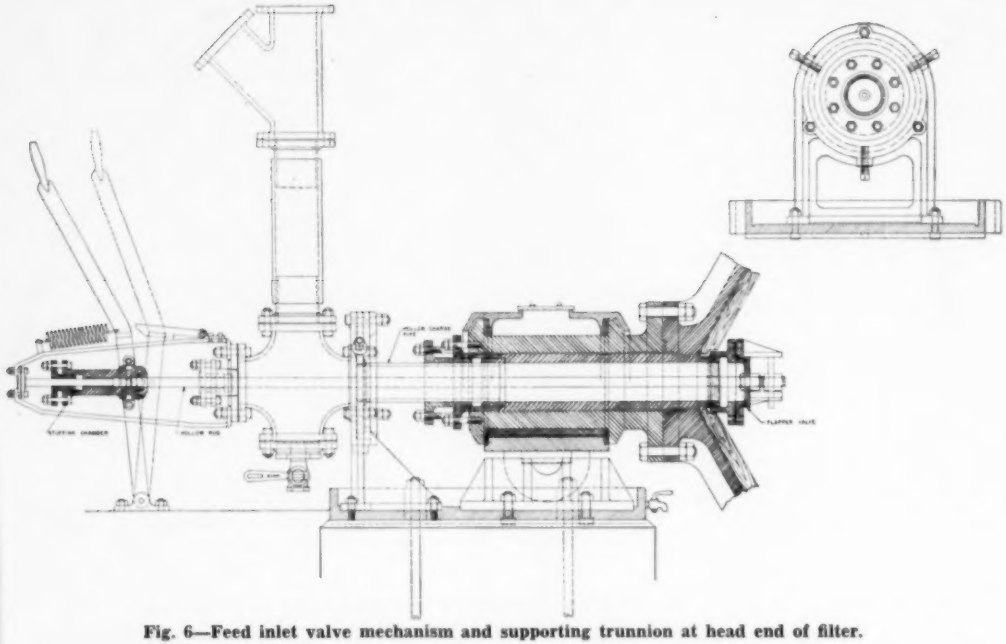


Fig. 6—Feed inlet valve mechanism and supporting trunnion at head end of filter.

miniature cloud at the center of the filter. The appearance of the cloud is so unmistakable that it is used to signify the end of filtration, and/or the end of any washing step. It is termed, locally, as a "blow."

(3) At the end of the first blow, the air is turned off and washing of the residue in the filter is begun. The recovery of the Burt solution still held in the residue is accomplished by applying successive washes each one of which is more dilute than the former. These washes, which begin as fresh water, are advanced from weaker to stronger washes as they gradually become enriched by repeated usage on the filters. Finally they become sufficiently concentrated to be disposed of in the leach.

Fig. 7—General view of feed end of a filter, showing separate and valves for rate pipelines various washes, air, vacuum and steam.

The first wash so added is termed "weak wash." When the pressure within the filter drops below 5 lb per sq in., approximately 4 vt (±950 gal) having a specific gravity of about 1.170 are forced into the filter maintaining the pressure of 5 lb. Valves are closed, air pressure to 40 lb per sq in. is applied, and the wash forced through the cake, consuming about 30 to 40 min. This wash will displace sufficient Burt solution entrained in the cake to raise the average specific gravity of the effluent to +1.300 (60°C). The filtrate is discharged to a sump and then to a tank reserved for "strong wash." This material is advanced directly to the leach where evaporation completes its concentration to ±1.540 sp gr (60°C). Again the vapor cloud denotes that the wash has gone through; the second "blow" has been reached.

(4) The second wash added is "weak wash," similar in specific gravity to the first. Approximately 5 vt (±1200 gal) are used. This is recirculated upon itself (pumped back to the "weak wash" tank) and consumes 20 to 25 min. The object of this step is to wash the residue down as near to the specific gravity of the weak wash as possible. Usually this objective is attained within 20 or 30 "points" of gravity. For example, if the weak wash is applied at sp gr = 1.170, the last several gallons of filter discharge just prior to the third blow will be sp gr 1.180 to 1.200.

(5) "Mull water," having a specific gravity of about 1.020 to 1.040, and in sufficient quantities to make up for the volume of weak wash advanced, is added as the final wash. About 4 vt will usually wash the residue so completely that the final solution discharge at the 4th blow will not exceed 1.050 to 1.080. All mull water used in this step is advanced to weak wash. Time consumed is 15 to 20 min.

(6) After the final blow, air is allowed to remain on for a few moments to force all possible effluent to weak wash, then the air is turned off and pres-

sure allowed to drop to zero. Five volume tons (±1200 gal) of mull water are added, the flapper valve left open, and vacuum is applied for 15 min. During this time the cake will be pulled from the canvas and mulled with water to form a thick slurry, which is usually free from all lumps and capable of smooth flow by the end of the vacuum period.

(7) Vacuum is stopped and the discharge ports are now opened to discharge the slurry to an open launder leading to conventional thickeners.

(8) Because the filter is level it will not completely discharge itself; it must be assisted by a flushing operation using about 5 vt of mull water. This final addition of mull water, applied with the discharge ports still open, sluices the residue from the interior of the filter and cleans the filter units. Rotation is stopped, one of the open ports spotted at lower dead-center, and the filter allowed to drain. The discharging, flushing, and draining takes about 40 min, including the 15-min vacuum period.

(9) When sufficiently drained, the filter is again closed, air is applied and rotation resumed. After 5 min the filter is blown dry and may be spotted at full-charge position ready to start the next cycle. If idle for any reason, the filter is kept warm by admitting low-pressure steam.

Operating Characteristics: Rotation of the Burt filter is necessary to its successful operation. By rotation the residue is not only evenly distributed over the filter units but the rotational movement keeps a quantity of pulp always moving over the surface of the cake which is thus continually sealed, whether it be a filtration or washing step, until all but a negligible amount of liquid has been discharged. This self-sealing action results in washing by displacement, which is more effective in removing entrained solution than washing by dilution.

Undue speed is not necessary. For zinc plant work, 4 rpm has been found satisfactory. Filters at this plant are equipped with controllers which permit set speeds of 2, 3, 4, and 6 rpm.

Filters are individually driven, each with a 20 hp motor, speed reducer, drive pinion, and master gear. Although full power load is maintained for short periods, consumption averages 15 hp per filter.

A small amount of cloudy filtrate will always appear when a filter is first charged and rotation begins. This is because some of the particles to be filtered are of lesser dimensions than the opening in the weave of the canvas bags. The cloudy condition persists for only a few minutes, however, due to the interstices of the cloth rapidly becoming partially blocked with larger particles, and from then on clear Burt solution is produced. Cloudy effluent does not appear in any subsequent washing steps, even when wash water is being applied to the filter.

Zinc plant data show that approximately 86 pct of the zinc sulphate available in the leach pulp charged to the filter is produced directly as Burt solution ready for further processing. The balance is trapped in the cake and must be recovered by washing and eventual recycling via the leach.

Metallurgical statistical figures for the year 1947 indicate that finished leach pulp, as delivered, contained 96.38 pct by volume of heavy zinc sulphate solution (sp gr = 1.540 at 60°C) and 3.62 pct by volume dry, solid residue (sp gr = 3.2). Per gallon of finished leach pulp the weight relationship, as delivered to the filters, was:

Burt solution	12.3861 lb per gal—	92.566 pct
Dry, solid residue	0.9948 lb per gal—	7.434 pct
Leach pulp	13.3809 lb per gal—	100.00 pct

Filters were invariably charged to capacity, so taking 4144 gal of pulp as norm, the total charge is 55,450 lb per cycle, consisting of 51,328 lb Burt solution (3836 gal or 16.0 vt) and 4122 lb dry residue.

In actual practice the total charge will be slightly larger than this due to the small amount of filtration which takes place while the filter is loading, and before the air is turned on. This additional volume will depend mainly on the filterability of the pulp.

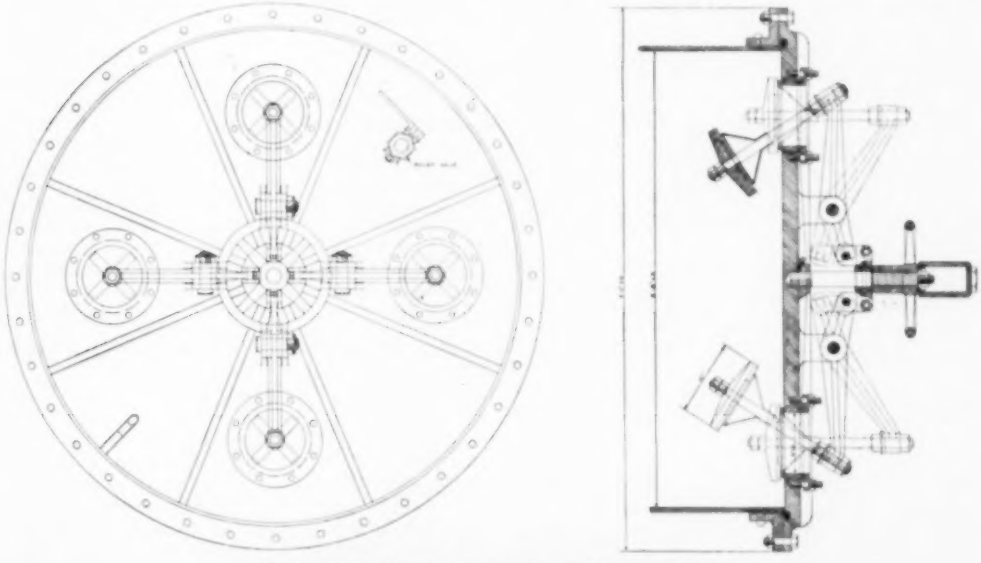


Fig. 8—Mechanism for discharging residue from filter.

It may be as low as 0.1 vt or as high as 1.0 vt. Some experimental work has been done in overcharging; that is, forcing the pulp into the filter under pressure with relief valve closed. This is entirely practicable as far as operation of the filter is concerned.

The wash-waters are kept separate in individual circuits which consist of sumps, storage tanks, pumps, and pipelines. Each circuit, however, whether it be strong wash (sp gr +1.300), weak-wash (sp gr ±1.150) or mull-water (sp gr ±1.030), is common to the entire installation of Burt filters.

Four parallel launders set at right angles to the long axis of the filters and directly under them, are provided for the filtrate as it spills from the discharge nipples into the collecting pan of each filter. A "swing-launder," anchored at one end but capable of being swung manually, by the filter operator, directs the filtrate from the collecting pan into whatever sump the solution should be placed. From the sumps it is pumped to storage tanks to be available for addition to leach or for delivery to whatever filter needs wash of that gravity. Live steam, at low pressure (±10 lb) is supplied through an open-end pipe under the solution surface in the storage tanks to keep the wash waters at 50° to 60°C.

The extent to which washing in Burt filters may be practiced, in any plant, will be governed by economic considerations. The principal factors affecting the amount of washing are: (1) Need for obtaining a clean residue. (2) Ease with which wash-waters may be converted into usable products, that is, the need for necessary volume control. (3) Time allowed, per total cycle, for the washing process.

In zinc plant metallurgy, where complete recovery of all entrained Burt solution is highly desirable, operations are directed toward obtaining the maximum wash consistent with a total cycle time not exceeding 3½ hr. As all wash waters are eventually disposed of in the leach, one method employed to wash the filters more thoroughly is to recirculate strong-wash whenever time permits.

Wash waters are delivered to the filters under a timing system. Pumps are first calibrated; then simple charts are established for the operators to follow. Signal timers indicating elapsed time, and equipped with warning lights, are installed at the head end of each filter to minimize errors. This simple system, followed successfully for a number of years, allows the department to keep the volumes of wash-waters continuously in balance by means of only three measurements of tanks per 24 hr, one set of measurements per 8-hr shift. Wash water effluents from the filters are directed toward their respective circuits at the beginning of every "blow" period.

Leach pulp volume	103.75 vt
Burt solution available in pulp (96.38 pct)	100.00 vt

			Phase of Cycle
Burt solution produced		86.38 vt	1st blow—filtration
Advanced to strong wash	10.84 vt		2nd blow—weak wash to strong wash
Collected in weak wash	1.95 vt		3rd blow—weak wash recirculation
Advanced to weak wash	0.35 vt		4th blow—mull water to weak wash
Burt solution washed		13.14 vt	
Total Burt solution recovered		99.52 vt	
Lost in residue		0.48 vt	vacuum filter discharge
		100.00 vt	

Zinc-plant metallurgical data for 1947 indicate the relationships (see table in col. 1) with regard to washing and recoveries within the Burt filters when filtering the type of pulp described in this paper.

Although the Burt filter performs a metallurgical task in a satisfactory manner it does not discharge a finished cake comparable to that of either a filter-press or vacuum drum or leaf filter. The Burt filter discharge is in the form of a slurry. If this slurry is to be pumped or laundered to some distant point, then the Burt has an inherent advantage. However if a dried or semidried product is wanted then the slurry must be rehandled. Zinc-plant practice is to settle in conventional Dorr thickeners, filter on Oliver vacuum drum-type filters, and dry to ±20 pct in rotary driers. The filtrate from the Olivers is returned to the mull-water circuit.

Filter-cloth life will vary from 25 to 60 days depending on the type of pulp being fed. Mechanical failure rarely causes more than 30 pct of filter-unit stoppage in the life-cycle of a set of bags. Actual ripping or tearing of the canvas allows mud to be discharged from the solution nipples, which is stopped by driving a wood plug into the nipple. Any filter unit thus plugged represents a decrease of 3.125 pct of the total filter area available, but this decrease is accepted for the life of the bags rather than to stop the filter, for replacement of the unit. Blinding of the bag by gypsum, a natural ingredient in zinc plant residue, is considered the major cause of short bag life. Other compounds may contribute, of course, but poor filtration capacity, due to blinding, fixes the practical life of a set of bags. When the total cycle time exceeds the permissible limit the filter is shut down and a freshly covered set of filter units installed. Core boards have a useful life of about 18 months, grooved surfaces about 12.

Experience has shown that one man can operate five Burt filters if the cycles are not shorter than three hr. The manipulation necessary to put through about fourteen cycles per 8-hr period constitutes a good shift's work. Over a period of one year filters will average six cycles per day, counting down-time for mechanical repairs and resacking of boards.

A crew of four men is ordinarily employed to renew a filter. Elapsed time for removing head, pulling old units, installing resacked units, closing filter, and checking for correct operation is 8 hr. In a continuous operation involving nine filters this same four-man crew resacks the filter units, assembles the filter boards from specially manufactured stock, and makes any necessary repairs thereto.

Sufficient air for nine Burt filters is supplied by a 500 cu ft per min compressor driven by a 75 hp motor at 300 rpm. One duplex vacuum pump, driven by a 30 hp motor at 300 rpm, having a displacement of 800 cu ft per min at 16 in. vacuum, services all filters and permits four filters to be on the vacuum line at once. Another similar vacuum pump is required by the Oliver filters. For zinc-plant work, pipelines are of copper, and pumps are of stainless steel. Wash-water tanks are unlined, of wood-stave construction. Sumps are of wood.

Burt filters could be operated with less individual attention if conditions warranted the installation of additional equipment. For example, wash-waters could be premeasured in separate tanks for automatic delivery to filters when required, and filtrates could be directed to proper circuits by automatic shifting of the swing-launder.

Effect of $BaCl_2$ and Other Activators on Soap Flotation of Quartz

Chemical conditions for flotation and nonflotation of quartz with oleic acid as collector and barium, calcium, aluminum, iron, and tin as activators were studied using a simple vacuum-flotation technique in glass-stoppered graduates. The detailed study of barium activation led to an interpretation based on ideal Langmuirian chemisorption.

by

R. Schuhmann, Jr.,

and

Brahm Prakash

FLOTATION of quartz is of practical importance as something to be avoided in soap-floating many types of ores. Clean, unactivated quartz is not floated with fatty acids and soaps, such as oleic acid and sodium oleate, in the quantities normally used for flotation. However, data in the literature indicate that almost any multivalent cation will activate quartz if given an opportunity. Thus, a common problem is to prevent activation of quartz by the various inorganic cations inevitably present in flotation pulps.

R. SCHUHMANN, JR., Member AIME, is Associate Professor, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass., and BRAHM PRAKASH, Student Associate AIME, was a Government of India Scholar, MIT.

This paper is based on a thesis submitted by B. Prakash in partial fulfillment of the requirements for the degree of Doctor of Science at MIT.

AIME New York Meeting, Feb. 1950.

TP 2826 B. Discussion (2 copies) may be sent to Transactions *AIME before June 30, 1950. Manuscript received July 26, 1949.*

Wark and his coworkers[1] have demonstrated the reversibility of the chemical reactions and adsorptions involved in the activation, depression, and collection of the common sulphide minerals. The procedure in much of their work was to bring a mineral surface to equilibrium with solutions of known pH, collector concentration, and activator concentration, and then to test the floatability of the mineral by contact-angle measurement. From the data, graphs were constructed with pH and reagent concentrations as coordinates. These graphs show fields of flotation and fields of nonflotation, separated by narrow transition regions whose locations are shown by so-called contact curves. From the shapes and locations of the contact curves, which roughly separate fields of flotation from fields of nonflotation, a quantitative understanding of the interaction of the reagents with each other and with the minerals often can be deduced.

The study of quartz flotation to be described in this paper follows in broad lines the approach of Wark and coworkers. That is, pH, activator concentration, and collector concentration were varied to find equilibrium conditions of flotation and nonflotation, and the results are presented graphically by means of contact curves. However, instead of testing for floatability by measuring the contact angle on a polished surface, a simple vacuum flotation technique was developed and used. Purified oleic acid was the collector and terpineol the frother. Barium activation was studied in some detail, and exploratory studies were made of activation with calcium, aluminum, ferric iron, and stannic tin.

Preparation of Materials

Quartz: Large lumps of high-grade vein quartz were crushed dry in a cone crusher and rolls. The —20, +28-mesh portion was screened out and used in the subsequent steps. This material was passed through a high-intensity magnetic separator to discard iron, then leached twice with hot concentrated HCl and washed repeatedly with distilled water. The cleaned sand was then wet ground with porcelain balls in a porcelain pebble mill, deslimed repeatedly by settling and decantation to discard —800-mesh material, and again washed with hot HCl followed by distilled water. The resulting stock of quartz was stored under water. Chemical analysis gave 99.8 pct SiO_2.

Table I gives the size analysis of the quartz used for flotation tests. Calculations from these data, using shape factors given by Gaudin and Hukki[2] indicate a specific surface of about 500 cm^2 per g.

Blank flotation tests in distilled water, and in water with added frother, showed the prepared quartz to be completely nonfloatable and thus indicated the absence of organic contamination.

Oleic Acid: The preparation of oleic acid was based on fractional vacuum distillation of methyl oleate[3, 2] followed by regeneration of oleic acid, and finally fractional crystallization of oleic acid from acetone solutions at low temperatures.[3] The pure oleic acid was stored in a refrigerator. The iodine number of the oleic acid was found to be 90.0 (theoretical 89.93).

Oleic acid was used in the form of a dilute water solution of sodium oleate, after preliminary flotation tests showed no effects of form of addition and order of addition of reagents when an adequate conditioning time (that is, 30 min) was provided.

Other Reagents: Sodium hydroxide solutions low in carbonate were prepared by first making 1:1

Table I. Size Analysis of Cleaned Quartz

Screen Size, Microns		Weight, Pct
—295	+208	10.4
—208	+147	21.3
—147	+104	18.5
—104	+74	28.0
—74	+52	12.2
—52	+37	8.5
—37	+18[a]	1.1
	—18[a]	0.0
Total		100.0

[a] Sedimentation size, calculated from Stokes' law.

aqueous solutions and centrifuging to separate the carbonate and other insoluble material. All metal salts used were of analytical reagent grade.

Experimental Procedures

Vacuum Flotation: The flotation cell consists of a standard, glass-stoppered graduated cylinder of 100-ml capacity. A large number of these graduates are kept on hand so that a dozen or so tests can be in progress at the same time. For lecture demonstration purposes a 1-liter graduate has been used with substantially the same technique as that used with the 100-ml cylinders.

About 1.2 g (±10 pct) of quartz is scooped out of the stock (under water) and transferred to the cylinder with clean, air-saturated distilled water. Reagents are added and the volume brought to about 100 ml. The glass stopper is inserted and the pulp then agitated for 30 min by tumbling end over end at 50 rpm. For this purpose a pair of brackets holding up to 12 100-ml cylinders was built onto the slow-speed shaft of a 1/20 hp gearmotor.

After the 30-min conditioning period, the graduate is removed from the agitator and the glass stopper replaced by a rubber stopper with a glass tube and stopcock, connected by suction tubing to a trap and to a water-aspirator vacuum pump. After applying the vacuum for a short time, flotation or nonflotation of the mineral is readily observed. If the mineral is at all floatable, the bubbles nucleate and grow on the mineral bed in the bottom of the graduate and then break loose carrying up a load of mineral. This process continues until all floatable mineral is lifted from the bottom. If the mineral is nonfloatable, a longer period of application of the vacuum is required before bubbles even start to form, and the bubbles will not carry a mineral load to the surface. Qualitatively, a considerable gradation in floatability can be observed as chemical conditions are changed gradually from conditions of nonflotation to conditions of complete flotation.

Use of air-saturated water to make up the pulps is preferred practice but is not essential since with sufficient vacuum the boiling of the water itself furnishes the bubbles for flotation. Care must be taken to use clean air in saturating the water. The best procedure is to draw laboratory air through a cleaning train and then through a closed gas-washing bottle containing the water to be saturated. A water aspirator is convenient for this purpose. The cleaning train consists of (1) an ascarite absorber, (2) concentrated NaOH wash bottle, (3) water wash bottle, and (4) trap. Compressed air from the laboratory supply line passed through this train retained enough organic contamination to cause mineral flotation without a collector.

Comparison of Vacuum Flotation and Captive-bubble Techniques: Previous studies of relationships between floatability and reagent concentrations have been based largely on the use of the captive-bubble technique of measuring contact angles. The main advantages of the vacuum-flotation technique used in this work over the captive-bubble technique are: (1) the apparatus is simpler, cheaper, and available in any laboratory; (2) less skill and special techniques are required; (3) the test is itself a flotation test, so that no assumption is made of a relationship between floatability and the contact angle on a prepared, plane surface; (4) the sensitivity is greater, as contact angles well under 10° are sufficient for flotation but are not detected by the captive-bubble method; (5) the mineral surface area is greater than that tested in a polished surface, thus giving reduced contamination hazard and reduced sampling error; and (6) the method permits rapid exploration if a large number of graduates and a suitable mechanical agitator are provided.

Determination of Critical pH: The principal variables in this work were pH, activator concentration, and collector concentration. The usual procedure was to make up a pulp (as already described) in the 100-ml graduate with given quantities of activator and collector and with 2-mg terpineol per liter to act as frother. With this pulp a series of flotation tests was carried out at varying pH. Sodium hydroxide (carbonate-free) and hydrochloric acid were used for pH control, and a full conditioning period was provided after each pH change to insure equilibrium. The pH was measured with a Beckman Model H, line-operated pH meter. The Beckman special high-pH electrode was used at high pH values.

When barium is used as activator, no flotation occurs with a given activator-collector combination below a certain critical pH. As the pH is raised above this critical value, quartz floatability increases rapidly so that complete and rapid flotation is obtained at pH values from 0.5 to 1.5 units above the lowest pH at which slight flotation can be detected. The quartz remains floatable as the pH is increased further. With activators other than barium, the variation of quartz floatability with pH may be more complex. Not only is there a "lower critical pH" below which no flotation occurs, but also there may be an "upper critical pH" above which there is no flotation. A few cases of more complex behavior have been observed, which involve two pH ranges in which flotation occurs.

In the vicinity of the critical pH, the change from incipient flotation to complete and rapid flotation takes place over a pH range of about one pH unit, and if the contact curve is oblique to the pH axis the critical range may extend several units. Also, it is to be expected that a change in particle size would shift the critical range somewhat, since to float as well as fine particles, coarse particles must be more air-avid. Thus, the critical pH is not a point of abrupt change from flotation to nonflotation, and this feature must be kept in mind in interpreting and using the data.

Critical pH values were checked by approach from both sides. Except for some inconclusive flotation tests with iron as activator, it was found that the value of the critical pH was the same whether approached from the high or low-pH side. Also order of addition of reagents had no effect on the

results. Thus, the chemical reactions and adsorptions involved are reversible, and the flotation tests were carried out under conditions close to chemical equilibrium.

Barium Activation of Quartz

Experimental: Critical pH determinations were made over the following ranges of reagent additions:

	Mg per Liter	Millieq. per Liter
Oleic acid	5-500	0.018-1.8
$BaCl_2 \cdot 2H_2O$	3-300	0.025-2.5

These concentrations cover the usual range of practical reagent concentrations. Thus 5 mg per liter = 5 ppm = 0.01 lb per ton of water, which is equivalent to 0.04 lb per ton of ore in a pulp 20 pct solids. For the very dilute pulps (about 1 pct solids) used in this work, the quantities of reagents abstracted by the mineral can account only for a very small fraction of the total reagent addition, since a reagent addition of only 1 or 2 mg per liter of pulp would be sufficient to form a monomolecular film on the quartz.

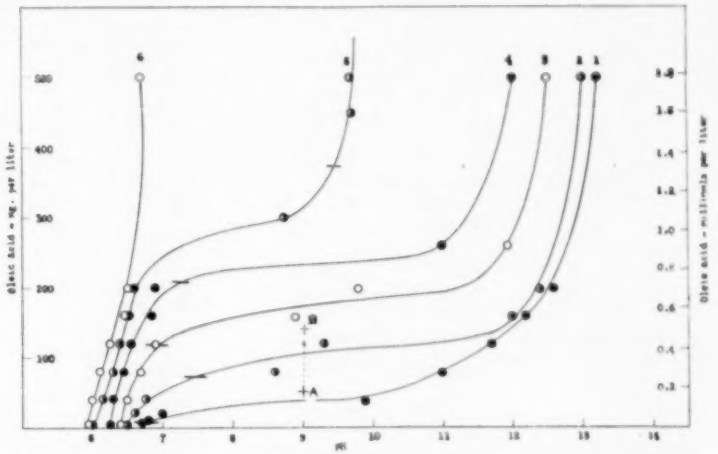


Fig. 1—Effects of $BaCl_2$ and oleic acid on critical pH for quartz flotation.

For given activator addition, flotation occurs under conditions below and to right of curve for that quantity of activator.

Curve No.	$BaCl_2 \cdot 2H_2O$ Mg per Liter
1	3
2	30
3	50
4	90
5	160
6	300

Figs. 1 and 2 give the experimental results plotted in two different ways. In fig. 1 the quantity of oleic acid is the ordinate and pH the abscissa, and each curve then shows the variation of critical pH with oleic acid addition for a fixed quantity of activator. In fig. 2, the ordinate is quantity of barium chloride so that each curve shows the variation of critical pH with barium chloride addition for a fixed quantity of collector. When the conditions represented by any one curve in either figure are considered, flotation occurs at conditions in the area to the right of the curve, and no flotation occurs under conditions to the left. The transition region from slight flotation to good flotation may be regarded as a band about 1 pH unit wide just to the right of the contact curve.

The contact curves in fig. 1 form a regular family of curves. With no activator added, no flotation occurs at any pH so no curve is given for 0 addition of $BaCl_2 \cdot 2H_2O$. Each of the curves can be divided into three parts, starting from the bottom left: (I) oleic acid addition below stoichiometric requirements to form $BaOl_2$, (II) transition region with curve substantially horizontal, and (III) oleic acid addition above stoichiometric requirements to form $BaOl_2$. The condition of stoichiometric equivalence of barium and oleate additions to form the normal oleate is indicated on each curve by a heavy dash. For curves 1 to 4 the dash falls on the horizontal parts of the curves within experimental error, for curve 5 the dash is a little above the horizontal part of the curve, and for curve 6 the oleic acid additions were not extended to the equivalence point.

When barium is in excess of that required to form barium oleate (part I of each curve), the critical pH falls in the range 6 to 7. No flotation occurs below the critical pH. Flotation occurs at all pH values above critical, including the pH of a normal sodium hydroxide solution. For the stoichiometric condition of excess barium, critical pH is relatively insensitive to reagent quantities.

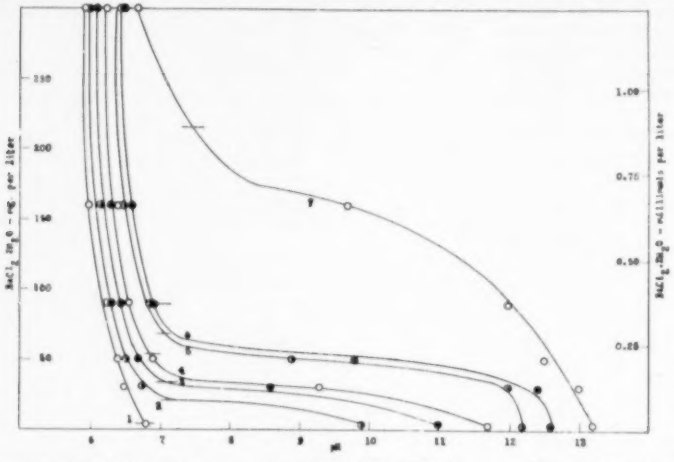
When oleate is definitely in excess of that required to form barium oleate (part III of each curve), the critical pH is well into the alkaline range so that flotation is possible only at a high pH. The critical pH is lowered and the pH range of flotation becomes greater as the quantity of activator is increased. For example, with 3 mg $BaCl_2 \cdot 2H_2O$ per liter and an excess of oleic acid the quartz floats only in strongly alkaline pulps above pH 13, but with 160 mg $BaCl_2 \cdot 2H_2O$ perliter and an excess of oleic acid the quartz floats at pH values as low as 11.

These results are in qualitative agreement with the experimental data of Gaudin and Rizo-Patron,[6] who found at a given pH (namely, 10.6) that most effective flotation was obtained with 1:1 mol ratio of oleate to barium and that flotation recovery fell off to approach zero as the 2:1 stoichiometric ratio was approached. However, their hypothesis, that these limiting ratios are the result of the fact that a barium ion adsorbed on quartz can hold only one oleate, is insufficient to account for our data since in our experiments only a small fraction of the total barium and oleate added can be accounted for on the quartz surface.

Action of oleic acid as a depressing agent can be seen by considering a given process in terms of the data in fig. 1. If a pulp is made up to pH 9 and contains 30 mg $BaCl_2 \cdot 2H_2O$ per liter and 50 mg oleic acid per liter, the pH and collector concentration are represented by point *A*. Point *A* is below and to the right of curve 2 for 30 mg $BaCl_2 \cdot 2H_2O$ per liter so that the quartz is floatable. If now we are unsatisfied with the way quartz floats under these

conditions and try to improve its flotation by adding more collector, we will move up toward *B*. We find that the more the collector, the worse the flotation, and in fact after crossing curve 2 at a collector concentration of about 100 mg per liter the quartz is depressed altogether by adding oleic acid while keeping pH and activator additions constant. After reaching this stage we can make the quartz float again either by adding more activator or by raising the pH to recross the curve.

Usually our interest is in depressing quartz after it has been activated unintentionally. The data in fig. 1 indicate several possible methods of depressing barium-activated quartz, the choice depending on stoichiometric relations in the pulp, as follows:



Initial Condition in Pulp	Procedure to Depress Quartz
Stoichiometric excess of Ba^{++} over oleate	Drop pH to below 6
	or
	Add excess oleate
Stoichiometric excess of oleate over Ba^{++}	Lower pH until quartz flotation stops; the greater the Ba concentration the lower the critical pH.

If these measures cannot be applied, other reagents may be necessary to deactivate the quartz by complexing or precipitating the barium.

Fig. 2 shows the same data as fig. 1 and is subject to the same explanation. Fig. 2 also shows clearly that increasing the barium chloride always lowers the critical pH and thus always increases the range in which quartz floats. Also, it can be seen that with any substantial excess of Ba over stoichiometric requirements for $BaOl_2$ (namely, above the flat portions of the curves), the critical pH is in the range 6 to 7 even for a 100-fold variation in oleic acid. (Curve 6 in fig. 1 also shows this.)

Activation, Collection, and Precipitation Reactions: Our data are consistent with the view that the quartz flotation is activator-controlled and not collector-controlled, provided only that there is enough oleate in the system to film the quartz when it does become activated. Two phenomena which would be expected in a collector-controlled system are absent: (*a*) There is no upper critical pH, corresponding to displacement of Ol^- by OH^- and depression as the pH is raised; (*b*) Even with a large excess of barium, several times more than required to precipitate the oleate as insoluble soap, no difficulty was experienced in collecting quartz, in fact, flotation was best under these circumstances.

The following equation may be written to represent the activation reaction at one locus of ruptured bond on the quartz surface:

$$\boxed{SiO_2}^{-H} + Ba^{++} + 2OH^- \rightleftarrows \boxed{SiO_2}^{-Ba\text{-}OH} + H_2O \qquad [1]$$

This equation is electrically balanced and represents the observed stoichiometry of base exchange in general, though perhaps not the true reaction mechanism. Stoichiometrically no distinction can be made between an increase of $2H^+$ in the solution per Ba^{++} adsorbed and the decrease of $2OH^-$ per Ba^{++} adsorbed by Eq 1. The abstraction tests of Gaudin and Rizo-Patron[5] indicated the reversibility of this reaction, as they found no abstraction of Ba^{++} by quartz in acid pulps and high abstraction in alkaline pulps.

Fig. 2—Effects of $BaCl_2$ and oleic acid on critical pH for quartz flotation.

For given collector addition, flotation occurs under conditions above and to right of curve for that quantity of collector.

Curve No.	Oleic Acid, Mg per Liter
1	5
2	40
3	80
4	120
5	160
6	200
7	500

After activation by Eq 1, collection can occur as follows:

$$\boxed{SiO_2}^{-Ba\text{-}OH} + Ol^- \rightleftarrows \boxed{SiO_2}^{-Ba\text{-}Ol} + OH^- \qquad [2]$$

Our data indicate that this reaction proceeds strongly to the right, as the quartz was not depressed by increasing OH^- and decreasing Ol^- within the range of conditions studied. That is, the pH was increased to 13.4 and the Ol^- reduced to a very small concentration by adding an excess of Ba^{++} and under these extreme conditions the quartz still floated.

The formation of a barium-soap precipitate (independent of the presence or absence of quartz) is represented by:

$$Ba^{++} + 2Ol^- \rightleftarrows BaOl_2 \text{ (ppt)} \qquad [3]$$

This reaction of course also proceeds strongly to the right, as the barium soap is known to be very insoluble.

The depressing effects of lowering pH and increasing Ol^- are accounted for by the following reaction:

$$\boxed{SiO_2}^{-BaOl} + H^+ + Ol^- \rightleftarrows \boxed{SiO_2}^{-H} + BaOl_2 \qquad [4]$$

This equation shows floatable quartz, filmed with oriented, partial monomolecular $BaOl^+$, returned to its original nonfloatable condition by replacing the $BaOl^+$ with H^+ and forming a separate $BaOl_2$ precipitate which does not help the quartz to float. Since both H^+ and Ol^- are reactants on the left-hand side of the equation, it is clear that decreasing pH

and increasing OI^- favor the formation of an insoluble barium oleate in preference to a BaOI film on the quartz, in agreement with our experimental results. A semiquantitative explanation of the experimental results, based largely on Eq 4, is developed in the subsequent sections.

Adsorption Equilibria and the Equilibrium Constant: For any chemical change at constant temperature, represented by

$$aA + bB + cC \rightleftarrows dD + eE + fF, \qquad [5]$$

equilibrium conditions can be expressed in terms of an equilibrium constant k, defined as follows:

$$k = \frac{(a_D)^d\,(a_E)^e\,(a_F)^f}{(a_A)^a\,(a_B)^b\,(a_C)^c} \qquad [6]$$

in which a_A, a_B, etc., represent the activities of the respective reactants relative to some arbitrarily fixed standard state for each reactant. This is a general relationship based on the second law of thermodynamics which applies whether the reactants are pure solids, liquids, or gases; or in liquid or solid solutions; *or in surface films, physically or chemically adsorbed; or in colloidal dispersions.* However, the equilibrium constant defined as above has not been used generally for adsorption equilibria for lack of activity measurements on substances in adsorbed films and because simple relations between activity and composition in adsorbed films (corresponding, for example, to Raoult's law for ideal solutions, Henry's law for dilute solutions, and the simple activity-partial pressure relation for perfect gases) have not been established.

Thus, to give the equilibrium constant quantitative significance for reactions in which one or more of the reactants is in the system as an adsorbed film, we must develop some measure of activity for substances in adsorbed films. Moreover, judging from the mass of experience with solutions, it may be helpful to define an *ideal* system for which activity is a simple function of the composition of the surface in which adsorption occurs. The deviations of actual systems from ideal behavior can be evaluated in terms of activity coefficients. If the ideal system is chosen properly, it may be possible to take the activity coefficient as unity for many practical systems.

Langmuirian Adsorption: Langmuir's ideal case of chemical adsorption on solid surfaces may be described as follows:* Adsorption occurs on specific atomic sites, which may be called "elementary spaces." These elementary spaces are all alike and equivalent. At any given instant, some of the spaces are occupied by units of the adsorbate (namely, atoms, molecules, ions) while some are empty. Kinetically, at a given instant, the adsorbed units may be "evaporating" or leaving some occupied sites and other units may be "condensing" on empty sites. At equilibrium the rate of evaporation from occupied sites must equal the rate of condensation on empty sites. For the most ideal system, each elementary space behaves independently of the others so that the force of attachment and the probable time of residence of an adsorbate unit on a given elementary space are not affected by the presence or absence of adsorbate on adjacent elementary spaces.

For the ideal case of Langmuirian adsorption, simple kinetic considerations* lead to the following equilibrium relation between mols adsorbed per unit area N_A, mols empty spaces per unit area N_e, and concentration in solution c_A:

$$\frac{\frac{N_A}{N_e}}{c_A} = k_A\dagger \qquad [7]$$

in which, at a given temperature, k_A is an adsorption constant characteristic of the adsorbate-adsorbent combination under consideration. Since Langmuir first derived a relation of this type and demonstrated its validity experimentally for several cases of adsorption of gases on solids, subsequent experimenters have found it valid for other adsorptions both from gases and from solutions. In general, it has proved most useful for adsorptions sometimes called chemisorptions in which the forces between adsorbate and adsorbent are specific and of the same order of magnitude as chemical bonds within a crystalline solid.

The adsorption of a given molecular species A from solution may be written formally:

$$A\,(\text{solution}) \rightleftarrows A\,(\text{adsorbed}) \qquad [8]$$

For this chemical change, the equilibrium constant is

$$k = \frac{a_A(\text{adsorbed})}{a_A(\text{solution})} \qquad [9]$$

The equilibrium constant becomes the same as k_A in Eq 7 if the customary assumption $a_A = c_A$ for dilute or ideal solutions is made and, if further, it is assumed that the activity of adsorbate a_A (adsorbed) is equal to the ratio of mols adsorbed N_A to mols empty spaces N_e.

In processes of ion adsorption, the solid surface can be regarded as having two kinds of elementary spaces, positive sites in which negative ions adsorb and negative sites in which positive ions adsorb. In an ideal case these may be considered independently, so that the activity of an adsorbed ion can be expressed in terms of the ratio of the number of the adsorbed ions to the number of empty spaces of the appropriate sign. If one multivalent ion occupies n adjacent sites, kinetic reasoning leads to the ratio $\frac{N_A}{(N_e)^n}$ as the appropriate activity function.

On the basis of the considerations in the preceding paragraphs, therefore, we propose that the activities of chemisorbed substances be compared with activities for the ideal case of Langmuirian adsorption, for which the activity of the adsorbed substance a_{ideal} *is proportional to the ratio* $\frac{N}{N_e}$ *of the number of adsorbed ions to the number of empty sites. If the adsorbed substance is an ion of charge* n *and occupies* n *single-charged sites on the surface,* a *should be taken as proportional to* $\frac{N}{(N_e)^n}$. *Deviations of a real system from ideality can be measured by means of an activity coefficient* (γ), *so that* $a_{non\text{-}ideal}$ *may be considered as proportional to* $\gamma\,\frac{N}{N_e}$ (or $\gamma\,\frac{N}{(N_e)^n}$).

* Rate of evaporation is proportional to number of occupied sites N_A. Rate of condensation is proportional to concentration c_A and to number of empty sites N_e. Equating these rates as an equilibrium condition leads to Eq 7.

† If there is only one species of adsorbate, this equation takes the more familiar form $\frac{\theta}{(1-\theta)c} = k_A$ in which θ is the fraction of elementary spaces occupied by adsorbate at equilibrium.

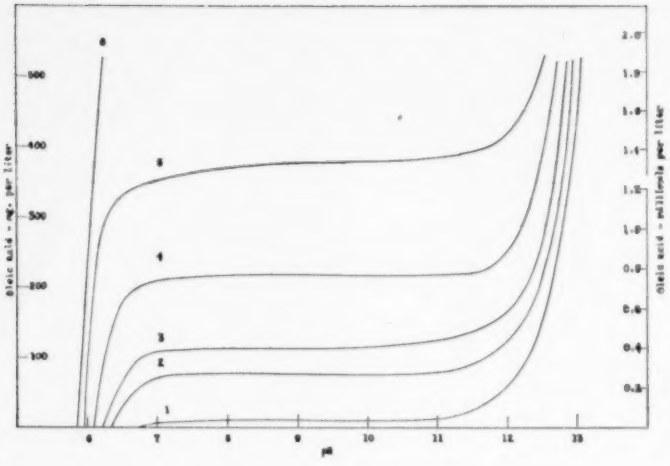


Fig. 3—Theoretical contact curves for quartz flotation with $BaCl_2$ and oleic acid.

Compare with experimental curves in fig. 1.

Curve No.	$BaCl_2.2H_2O$ Mg per Liter
1	3
2	30
3	50
4	90
5	160
6	300

Equilibrium Constants for Reactions Involving Adsorbed Reactants: Earlier it was pointed out that the equilibrium conditions for a reaction involving a surface could be expressed in terms of a mass-action constant if a suitable measure of the activity of substances in the surface was available. Accordingly, the activity concept for adsorbed substances developed in the preceding section affords a basis for applying the mass-action law to reactions involving one or more adsorbed reactants.

A simple exchange adsorption may be represented by:

$$A \text{ (adsorbed)} + B \text{ (solution)} \rightleftarrows B \text{ (adsorbed)} + A \text{ (solution)} \qquad [10]$$

If we assume that the adsorptions of A and B are ideal Langmuirian adsorptions and that the solutions follow Henry's law of dilute solutions, the mass-action constant for this reaction becomes simply:

$$K = \frac{C_A N_B}{C_B N_A} \qquad [11]$$

in which C_A, C_B are the concentrations in solution and N_A, N_B are the surface concentrations (namely, mols adsorbate per unit area). The number of empty spaces N_s cancels out and does not appear in the equilibrium constant.

Data for ion exchange on various commercial adsorbents, such as the ion-exchange media used for water softening, are well correlated by mass-action constants of the form of Eq 11. In fact, workers in this field have also derived such mass-action expressions on a theoretical basis similar to that of the foregoing discussion.[7]

Application of Mass Action to Reactions in Quartz Flotation: For reactions 1 to 4 in the quartz-flotation system, the mass-action constants can be written as follows, assuming ideal Langmuirian behavior of adsorbates:

$$k_1 = \frac{(N_{BaOH})}{(N_H)\ (Ba^{++})\ (OH^-)^2}$$

$$k_2 = \frac{(N_{BaOl})\ (OH^-)}{(N_{BaOH})\ (Ol^-)}$$

$$k_3 = \frac{1}{(Ba^{++})\ (Ol^-)^2}$$

$$k_4 = \frac{(N_H)}{(N_{BaOl})\ (H^+)\ (Ol^-)}$$

The equilibrium constant k_1 deals with the adsorption of Ba^{++} on quartz in the absence of oleate, for which we have no data. Since, as already discussed, reaction 2 goes strongly to the right under all conditions tested we can say only that k_2 is very large and that no appreciable quantity of adsorbed BaOH is present in the systems with oleate added. In other words, the elementary spaces available for ion adsorption are occupied either by H or by BaOl or they are empty. The stoichiometry of ion exchange adsorptions and the usual preservation of electrical balance indicate that the proportion of empty spaces is very small, so that in our systems for practical purposes, $N_H + N_{BaOl}$ should account for substantially all the elementary spaces. Thus we are left with the equilibrium constants k_3 and k_4, to account for our experimental data.

The contact curves in fig. 1 represent the borderline conditions between floatability and nonfloatability, and thus for a surface covered with —H and —BaOl groups correspond to a limiting value of $\frac{N_{BaOl}}{N_H}$ below which the surface is too hydrophilic for flotation. Thus, re-arranging the expression given above for k_4,

$$(H^+)\ (Ol^-) = \frac{N_H}{N_{BaOl}\ k_4} = \text{constant along contact curve.}$$

Taking a constant value of 1.6×10^{-10} for $\frac{N_H}{N_{BaOl}\ k_4}$ along the contact curve and a value of 6.5×10^{27} for k_3*, the family of theoretical contact curves shown in fig. 3 was calculated to correspond to the experimental curves given in fig. 1. The two numerical constants were chosen by trial and error to give the best agreement between experiment and theory.

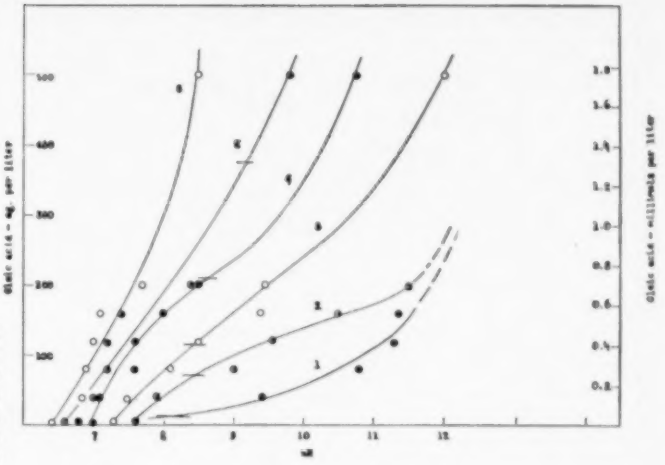
* These values are for concentrations expressed as mols per liter.

Calculations for the curves were based on the following, in addition to the equilibrium constants already given: $(H^+) = 10^{-pH}$. With oleate added in stoichiometric excess over barium: (Ol^-) = mols HOl added per liter — 2 × (mols $BaCl_2$ added per liter). With barium in stoichiometric excess: (Ba^{++}) = mols $BaCl_2$ added per liter — ½ × (mols HOl added per liter). The last two relations represent the fact that the quantities of reagents which react to form the $BaOl_2$ precipitate must be subtracted from the added quantities in calculating actual ion concentrations.

Fig. 4—Effects of $CaCl_2$ and oleic acid on critical pH for quartz flotation.

For given activator addition, flotation occurs under conditions below and to right of curve for that quantity of activator.

Curve No.	$CaCl_2$ Mg per Liter
1	2.3
2	13.6
3	22.7
4	40.9
5	72.6
6	136.2



Comparison of the experimental curves in fig. 1 with the theoretical curves in fig. 3 shows a remarkable similarity, especially when it is kept in mind that the positions and shapes of the theoretical curves were fixed by choice of only two arbitrary constants for the whole family of curves. We believe the correspondence close enough to represent strong support of the validity of the chemical equations given earlier in accounting for the behavior of barium-activated quartz.

Closer comparison of experimental and theoretical curves, however, shows serious deviations from the proposed ideal behavior when the oleic acid is present in stoichiometric excess over the barium; that is, in the upper right-hand legs of the curves in figs. 1 and 3. The deviations might be described as follows: In the theoretical development, it was assumed (1) that a stoichiometric precipitate of $BaOl_2$ is formed and has a definite solubility product and (2) that this precipitate itself does not affect the floatability of quartz. These assumptions lead to the conclusion reflected in fig. 3 that critical pH should be independent of the amount of $BaOl_2$ precipitate and independent of the amounts of Ba^{++} and HOl added separately but reacting in solution to form the precipitate. The experimental data show a definite variation of critical pH with calculated quantity of $BaOl_2$, indicating that for alkaline pulps with excess soap assumption 1 or 2 above, or both might be in error. As will be seen, this deviation becomes even more marked with calcium activation.

Calcium Activation of Quartz

Vacuum-flotation tests of calcium activation were made over the following ranges of reagent additions:

	Mg per Liter	Millieq. per Liter
$CaCl_2$	2 - 136	0.04 - 2.5
Oleic acid	5 - 500	0.018 - 1.8

The contact curves are given in fig. 4. These curves are broadly similar to those for barium-activated quartz, in that the critical pH is markedly increased by increasing the quantity of oleic acid. Also, within the pH range 8 to 10 the quartz is floatable if the molal ratio Ol:Ca is less than about 2:1 (indicated by heavy dash across contact curves), but is not floatable if the oleate is definitely in excess of this ratio. Thus, as with Ba, there are conditions under which Ca-activated quartz can be depressed by adding excess oleic acid. As with Ba, we believe the oleic acid deactivates the quartz, putting the Ca into the form of the insoluble soap, by a reaction analogous to reaction 4. We have observed related phenomena in soap flotation of tin ores in moderately hard water. That is, first addition of collector produced a high-silica, nonselective froth and subsequent conditioning with more collector decreased the quartz content of the float.

Calcium, unlike barium, exhibited an upper critical pH above which the quartz did not float. Because of difficulties in measuring the very high pH values, no pH data are reported. However, quartz did not float with Ca activation in 1-normal sodium hydroxide. These observations correlate with the fact that $Ca(OH)_2$ is less soluble than $Ba(OH)_2$. Hence it is possible that nonflotation above the upper critical pH is due to displacement of Ol by OH at the Ca-activated surface; that is, the Ca reaction corresponding to Eq 2 is reversible at high pH values. Another explanation is that above the upper critical pH the Ca precipitates as $Ca(OH)_2$, leaving the Ca^{++} concentration in solution too low to maintain activation.

Although the Ca-activation data show the same general trends as the Ba-activation data, the Ca-activation data deviate much further from expectations based on the theory given earlier for Ba-activation. These deviations are most marked with oleic acid in stoichiometric excess over calcium. Under these conditions, the critical pH appears to be a function of quantity of calcium added. If all the calcium were precipitated as $CaOl_2$ it would be expected that the concentration of Ca^{++} and hence its action as an activator would be controlled by the solubility product of the $CaOl_2$, and would be independent of the quantity of calcium in the precipitated form.

The data for barium and calcium activation afford some understanding of the practical problem of soap floating in hard water, without floating quartz. In the pH range from neutrality up to pH 10 or 11 quartz tends to float when either Ba or Ca is in stoichiometric excess over oleic acid. If the quantity of Ba or Ca is not too great, the quartz flotation can be overcome by increasing the collector addition.

Aluminum Activation

Before making flotation tests with aluminum as activator, a series of potentiometric titrations were made to gain a little acquaintance with the chemical reactions in solutions to which aluminum and

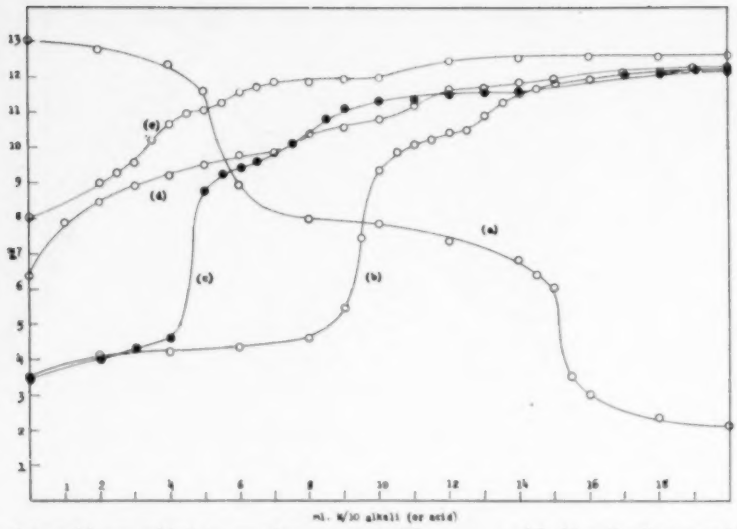


Fig. 5—Titration curves for $AlCl_3$, HOl, and mixtures.

Curve No.	Initial Solution	Titrated with
(a)	10 ml N/10 HOl + 15 ml N/10 NaOH	HCl
(b)	10 ml N/10 $AlCl_3$	NaOH
(c)	5 ml N/10 HOl + 5.5 ml N/10 NaOH + 10 ml N/10 $AlCl_3$	NaOH
(d)	7.5 ml N/10 HOl + 7.5 ml N/10 NaOH + 7.5 ml N/10 $AlCl_3$	NaOH
(e)	10 ml N/10 HOl + 10.5 ml N/10 NaOH + 5 ml N/10 $AlCl_3$	NaOH

oleic acid are added in varying amounts. The resulting titration curves are given in fig. 5. Our interpretations of these data are as follows:

1. Sodium oleate reacts with a strong acid to produce oleic acid in the pH range 7 to 8. Below pH 7 then, added oleic acid will be present largely as undissociated acid; above pH 8, added oleic acid will be largely in the form of oleate ions (fig. 5*a*).

2. Aluminum precipitates as $Al(OH)_3$ in the vicinity of pH 4. Further additions of alkali raise the pH and then between 9.5 and 11 the precipitate dissolves as AlO_2^- (fig. 5*b*).

3. Aluminum oleate is stable below pH 7, at least down to pH 4 (fig. 5*c*) and perhaps well below pH 4.

4. As the pH is increased from 8 to 12, aluminum oleate reacts with alkali, probably in several steps. Elliott[6] has indicated the existence of mono, di, and tri-soaps. When the pH reaches 12, all the soap is dissolved with the formation of AlO_2^- and Ol^- (fig. 5*d*,*c*,*e*). This conclusion fits the stoichiometry of the titration curves and checks also with the observed dissolution of precipitated soap at high pH values.

The vacuum-flotation tests of aluminum activation covered wide ranges of reagent additions in an exploratory fashion:

	Mg per Liter	Millieq. per Liter
$AlCl_3$	0.3 - 285	0.006 - 6.4
Oleic acid	0.7 - 360	0.0025 - 1.3

As might be expected, flotation behavior with Al-activation is somewhat more complex than with Ba-activation. In particular, Al-activation showed both a lower and an upper critical pH, with flotation between the two, and nonflotation outside the two limits.

To avoid confusion from overlapping curves, the data are plotted in two separate graphs, fig. 6*a* for smaller amounts of activator (0.3 to 18 mg per liter) and fig. 6*b* for larger amounts of activator (18 to 285 mg per liter). In these tests it was found more convenient to determine the critical pH for near-complete flotation rather than the critical pH for incomplete flotation (as was done with Ba-activation).

The upper critical pH falls in the range 12 to 13, regardless of the quantities of activator and collector added. This upper pH limit to quartz flotation with Al-activation may be accounted for by the fact that Al^{+++} is converted to AlO_2^- at high alkalinities.

For each quantity of activator, there is a wide range of collector additions giving a lower critical pH between 4 and 5. Effective flotation from a lower critical pH of 4 to 5 up to an upper critical pH of 12 or 13 was observed when the oleic acid was below stoichiometric equivalence to the formation of $Al(Ol)_3$ with the activator. As the oleic acid was raised above this equivalence point, the lower critical pH increased rapidly so that with an excess of oleic acid, flotation was possible only in a narrow pH range near 12 (fig. 6*a*). Thus, as with Ba and Ca, we believe that excess oleic acid deactivates the quartz by converting the Al into an insoluble soap precipitate by a reaction similar to reaction 4.

Lower critical pH remained from 4 to 5 with more than 10-fold excess of activator, but with very large ratios of activator to collector (bottom portions of fig. 6*b*) the critical pH increased to give a narrower flotation range. No explanation of these effects should be attempted without more experimental data.

Iron Activation

Iron, both ferrous and ferric, is a common constituent of flotation pulps. Ferrous salts are unstable in the presence of air, especially in neutral or alkaline pulps, so our experiments were confined to ferric activation.

A number of potentiometric titrations were made to explore the reactions between ferric salts, oleic acid, and alkalis. Results were as follows:

1. Ferric hydroxide forms between pH 2 and 3. The precipitate did not flocculate until the pH reached about 7 (fig. 7*a*).

2. Ferric oleate is stable over the pH range from below 2 to above 7, neither decomposing to yield oleic acid at low pH nor reacting with alkali to form ferric hydroxide at high pH (fig. 7*b*,*c*,*d*). In fig. 7*d* the inflection between pH 7 and 8 corresponds to the saponification of the excess oleic acid.

The vacuum-flotation tests of iron activation did not yield reproducible and consistent results, showing that a great deal of study involving other than flotation techniques may be necessary to elucidate the various phenomena involved. In the first place,

the phenomena were not reversible so that the floatability depended upon the procedure used in preparing the pulp. Secondly, precipitates formed from the solution tended to smear the quartz visibly.

Exploratory vacuum flotation tests of ferric activation covered the following ranges of reagent addition:

	Mg per Liter	Millieq. per Liter
$FeCl_3$	0.3-175	0.006-3.2
Oleic acid	1.8-450	0.006-1.6

The data are too rough to justify the plotting of contact curves, but did bring out some points of interest:

1. Ferric iron activates quartz at pH values from as low as 3 to as high as 12. That is, it can serve as activator under conditions where Fe^{+++} concentration must be extremely low, owing to precipitation of the hydroxide. This is consistent with the titration data, which indicated ferric oleate to be more stable than ferric hydroxide.

2. Both a lower and an upper critical pH were always found. Quartz was not floated under any conditions below a lower critical pH of 3 or above an upper critical pH of 12.

3. For a given quantity of activator, flotation was possible only with collector additions within a less than 10-fold variation from stoichiometric equivalence to the activator. Large excesses of either activator or collector resulted in nonflotation.

4. Various complexities were observed, some more or less reproducible, such as an additional pH range of nonflotation between the lower and upper critical pH.

Tin Activation

Quartz could not be floated at any pH with stannic chloride as activator (35 to 175 mg per liter) and oleic acid (18 to 150 mg per liter). Since stannous salts oxidize easily to stannic under flotation conditions, it appears likely that tin is not a quartz activator in the soap flotation of tin ores.

Summary and Conclusions

Chemical conditions for flotation and for nonflotation of quartz with oleic acid as collector and barium, calcium, aluminum, iron, and tin as activators were studied. A vacuum-flotation technique using standard 100-ml glass-stoppered graduates as flotation cells was developed and used for all the experimental work. The experimental procedure was to vary the quantities of collector and activator, and for each reagent combination to determine the critical pH which roughly separates conditions of flotation from conditions of nonflotation.

Except for iron activation, the critical pH could be approached from either side and did not depend

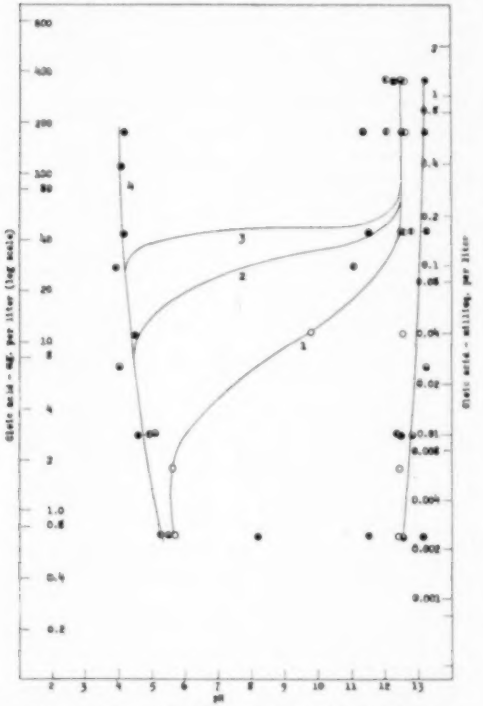


Fig. 6a—Effects of $AlCl_3$ and oleic acid on pH range for quartz flotation.

For given activator addition, flotation occurs under conditions between corresponding lower critical pH curve at left and upper critical pH curve at right.

Curve No.	$AlCl_3$ Mg per Liter	$AlCl_3$ Millieq. per Liter
1	0.3	0.006
2	1.1	0.025
3	4.5	0.1
4	18.0	0.4

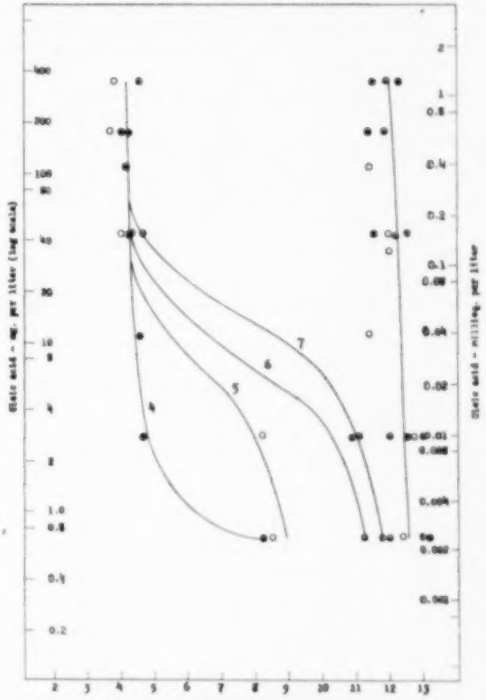


Fig. 6b—Effects of $AlCl_3$ and oleic acid on pH range for quartz flotation.

For given activator additions, flotation occurs under conditions between corresponding lower critical pH curve at left and upper critical pH curve at right.

Curve No.	$AlCl_3$ Mg per Liter	$AlCl_3$ Millieq. per Liter
4	18	0.4
5	36	0.8
6	142	3.5
7	285	6.4

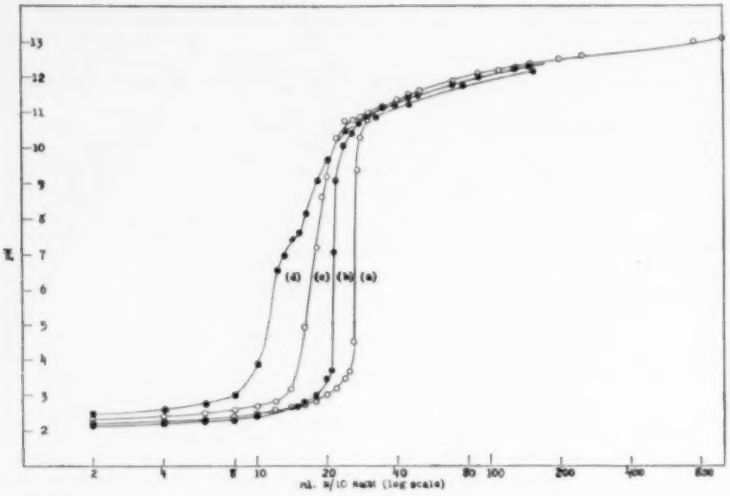


Fig. 7—Titration curves for $FeCl_2$, HOl, and mixtures.

Curve No.

(a) 10 ml N/10 $FeCl_2$ + 16 ml N/10 HCl

(b) 10 ml N/10 $FeCl_2$ + 16 ml N/10 HCl + 50 ml N/100 NaOl

(c) 10 ml N/10 $FeCl_2$ + 16 ml N/10 HCl + 100 ml N/100 NaOl

(d) 10 ml N/10 $FeCl_2$ + 16 ml N/10 HCl + 150 ml N/100 NaOl

on order of reagent additions. Thus many of the reactions and adsorptions involved in soap flotation of quartz are reversible, and chemical equilibrium can be closely approached during conditioning. Accordingly, a modified mass-action relation was developed for reactions involving adsorbed substances. This relation is based on Langmuirian chemisorption as an ideal case.

Specific conclusions are summarized below:

1. Ba^{++}, Ca^{++}, Al^{+++}, and Fe^{+++} all serve as activators for quartz over wide pH ranges, provided they are present in stoichiometric excess over the quantities required to form normal soaps with the oleic acid. Ba^{++} and Ca^{++}, however, are effective activators only above pH 7 or so, whereas Al^{+++} and Fe^{+++} are effective over most of the pH range from 4 to 12 or 13.

2. An excess of oleic acid over the quantity required to form a normal soap with the activator tends to depress quartz, in that flotation is possible only at relatively high pH values. This can be accounted for by a deactivation reaction which removes the activating cation from the quartz into a very insoluble metal-soap precipitate.

3. Except possibly at high pH values (namely, 12 and above) flotation or nonflotation of quartz is contingent primarily on activation or nonactivation; collection of activated quartz takes place if oleate is present in the system in small amounts in any form. Bases of this conclusion are:

a. Upper critical pH values, which might correspond to displacement of Ol by OH at the quartz surface, are very high (12 or above for Al, Fe, Ca) or nonexistent (Ba).

b. Adding large excesses of metal ions over the quantities required to precipitate all added oleic acid as insoluble soaps does not depress the quartz.

4. Flotation or nonflotation of quartz is related to equilibria in reactions of the type:

$$\underset{\text{Floatable quartz}}{\boxed{SiO_2}^{-Ba\cdot Ol}} + H^+ + Ol^- \rightleftharpoons \underset{\text{Nonfloatable quartz}}{\boxed{SiO_2}^{-H}} + BaOl_2 \text{ (ppt)}$$

For the specific case of barium activation, application of mass-action reasoning to this reaction leads to the relation $(H^+)(Ol^-) =$ constant for borderline conditions between flotation and nonflotation. The experimental critical-pH curves approximate the theoretical curves calculated from this relation.

5. Aluminum and ferric iron are effective quartz activators in pulps where the concentrations of aluminum or ferric ions must be very small, owing to their precipitation as hydroxides.

6. Stannic tin does not activate quartz.

References

[1] I. W. Wark: Principles of Flotation. Australasian Inst. of Min. and Met. (1938).

[2] J. C. Smith: Higher Aliphatic Compounds. VIII, Purification of Oleic and Elaidic Acids. *Jnl.* of Amer. Chem. Soc. 974-980 (1949).

[3] D. H. Wheeler and R. W. Riemenschneider: Preparation and Properties of Highly Purified Methyl Oleate. *Oil and Soap* (1939) **16**, 207.

[4] J. B. Brown and A. Y. Shinowara: Preparation of Pure Oleic Acid by a Simplified Method. *Jnl.* of Amer. Chem. Soc. (1937) **59**, 6-8.

[5] A. M. Gaudin and A. Rizo-Patron: The Mechanism of Activation in Flotation. *Trans.* AIME (1943) **153**, 462.

[6] I. Langmuir: The Constitution and Fundamental Properties of Solids and Liquids. Part I. Solids. *Jnl.* of Amer. Chem. Soc. (1916) **38**, 2221-2295. Also, The Adsorption of Gases on Plane Surfaces of Glass, Mica, and Platinum. *Jnl.* of Amer. Chem. Soc. (1918) **40**, 1361-1403.

[7] G. E. Boyd, J. Schubert, and A. W. Adamson: The Exchange Adsorption of Ions from Aqueous Solutions by Organic Zeolites. I. Ion-exchange Equilibria. *Jnl.* of Amer. Chem. Soc. (1947) **69**, 2818-2829.

[8] S. B. Elliott: The Alkaline-Earth and Heavy-Metal Soaps. Page 183. Reinhold Publishing Company (1946).

[9] A. M. Gaudin and R. T. Hukki: Principles of Comminution—Size and Surface Distribution. *Trans.* AIME (1946) **169**, 67; *Min. Tech.* (Nov. 1944), TP 1779.

The authors' attention has been called to the following papers which have appeared since their paper was submitted for publication and which present a more detailed study of some aspects of the calcium activation of quartz than that presented herein.

[10] S. R. B. Cooke and M. Digre: Studies on the Activation of Quartz with Calcium Ion. *Trans*, AIME, **184**, 299-305; *Min. Eng.*, Aug. 1949.

[11] S. R. B. Cooke: The Flotation of Quartz Using Calcium Ion as Activator. *Trans.* AIME, **184**, 306-309; *Min. Eng.*, Aug. 1949.

Effects of Activators and Alizarin Dyes on Soap Flotation of Cassiterite and Fluorite

by
R. Schuhmann, Jr.,
and
Brahm Prakash

Chemical conditions for flotation and nonflotation of cassiterite and fluorite with oleic acid as collector and with alizarin dyes as modifying agents were studied by means of small-scale, vacuum-flotation tests. Artificial cassiterite was prepared for these tests by high-temperature methods, especially by crystallization from borax melts.

FLOTATION test work on Bolivian tin ores some years ago led to the development of several workable schemes of selective soap flotation, but left unanswered many questions of soap-flotation chemistry.[1] Accordingly, the study of the activation and soap flotation of quartz just reported[2] was undertaken as a start toward the elucidation of some of the unanswered questions. The experimental work on quartz flotation consisted primarily of small-scale, vacuum-flotation tests in which activator and collector additions and pH were varied between wide limits.

In the work to be described in this paper, the soap flotation of cassiterite and fluorite was studied by the vacuum-flotation technique developed in the previous study of quartz. Using oleic acid as collector, conditions for floating cassiterite and fluorite in the absence of modifying agents were first determined. Then the effects of barium, calcium, and alizarin dyes on the flotation of cassiterite, fluorite, and quartz were studied. Alizarin dyes were chosen for study because of the promise they have shown as selective modifying agents in the flotation of nonsulphide minerals.[3,4] Also, they form a family of reagents in which there should be a systematic correlation of chemical properties with composition. As a preliminary to the study of cassiterite flotation, an investigation of the preparation of synthetic cassiterite and X ray studies of natural and synthetic cassiterite were undertaken.

R. SCHUHMANN, JR., Member AIME, is Associate Professor, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass., and BRAHM PRAKASH, Student Associate AIME, was a Government of India Scholar, MIT.

This paper is based on a thesis submitted by B. Prakash in partial fulfillment of the requirements for the degree of Doctor of Science at MIT.

AIME New York Meeting, Feb. 1950.

TP 2827 B. Discussion (2 copies) may be sent to Transactions *AIME before June 30, 1950. Manuscript received July 26, 1949.*

Experimental Methods

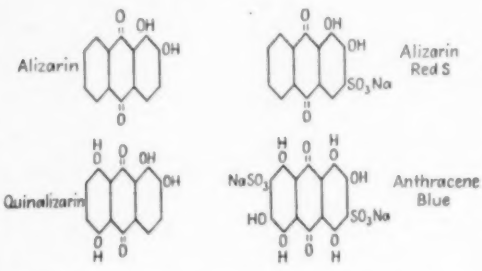
The flotation technique and most of the reagent preparations were described fully in the previous paper.[2] In addition, for the present work it was necessary to prepare satisfactory stocks of clean cassiterite and fluorite and to obtain samples of alizarin dyes.

Cassiterite: High-grade cassiterite from the Netherlands East Indies was crushed, sized, and cleaned

carefully by gravity and magnetic separation. The concentrate was wet ground, deslimed, and then leached with hot HCl twice and washed thoroughly with distilled water. The product was not floatable with a frother alone. However, the mineral was still brown and analyzed only 97.5 pct SnO_2. Other chemical treatments with strong alkali and HF, also ignition at 1100°C, did not improve the color or purity. Hence, it seemed desirable to attempt the artificial preparation of cassiterite, to avoid a possible error from the presence of an activating constituent in the natural mineral. Details of making the artificial cassiterite are given in a subsequent section.

Fluorite: Fluorite crystals free from interference colors were hand-picked from a stock of high-grade material (99.6 pct CaF_2) originally obtained from Ward's Natural Science Establishment. The selected pieces were extracted with ether in a Soxhlet-type apparatus. Subsequent steps in preparation were: (1) wet crushing in mortar and pestle, (2) pebble-mill grinding, (3) alkali leach (4) HCl leach, (5) washing, and (6) desliming at 18 microns. The deslimed product was stored under water. It was all minus 200 mesh, plus 18 microns and had an estimated specific surface of 1500 cm^2 per g. It was not floatable with a frother alone.

Alizarin Dyes: The four dyes tested as flotation reagents were the following:



As the formulas show, these dyes are similar structurally but differ in the numbers and locations of —OH and —SO_3Na groups substituted for —H in the common anthraquinone structure.

Alizarin and alizarin red S were of indicator grade and supplied by Allied Chemical and Dye Corp. Quinalizarin was Eastman, high-purity dye. The Anthracene blue W.R.S. was of commercial grade supplied by E. I. du Pont de Nemours and Co.

Synthesis of Cassiterite and X Ray Studies*

* The authors wish to acknowledge the generous assistance, both in advice and in making equipment available, given in the X ray studies by Prof. J. T. Norton of the Metallurgy Department and Mr. A. J. Frueh of the Geology Department, MIT.

A variety of syntheses of crystalline stannic oxide are described in the literature, but experimental details and proofs of identity of the products are meager. Two methods were selected and tried:

1. Reaction of $SnCl_4$ and H_2O in a hot tube.[3]
2. Crystallization from borax, stannic oxide melts.[4, 5]

The cassiterite used for flotation tests was prepared eventually by crystallization from borax melts, but some interesting results were obtained in attempting to react stannic chloride and water.

Reaction of $SnCl_4$ and H_2O: First, thermodynamic calculations were made which checked the feasibility of forming SnO_2 at temperatures around 1000°C by the reaction:

$$SnCl_4(g) + 2H_2O(g) \rightarrow SnO_2 + 4HCl(g)$$

The thermodynamic data were taken from Kelley.[6] After considerable preliminary experimentation the apparatus was set up as follows: The reaction tube was either an alundum or a Vycor combustion tube passing through a Burrell furnace which could be held at any desired temperature up to well over 1000°C. Stannic chloride gas and steam, each mixed with nitrogen, were introduced separately into the reaction tube. Quantities of $SnCl_4$ and H_2O were each controlled as follows: A metered flow of N_2 was saturated with the vapor at a preset temperature by bubbling the N_2 through the liquid ($SnCl_4$ or H_2O) held in a container in a heated oil bath. Vapor-pressure data from Stull's compilation[7] were used in calculating the flow rates of $SnCl_4$ and H_2O. Generally a small stoichiometric excess of $SnCl_4$ was used.

Variations in temperature (range 800 to 1000°C), flow rates, $SnCl_4$ to H_2O ratio, positions of inlet tubes, and so on, gave a variety of crystalline deposits of various colors in the refractory tube. However, the yields were consistently very small and the colors were suggestive of contamination. Crystals from one run at 800°C were carefully separated for analysis, and contained 99.1 pct SnO_2. Debye-Scherrer diffraction patterns indicated this material to be crystallographically identical with natural cassiterite and with artificial cassiterite prepared by crystallization from borax melts.

In one run at 1000°C an alundum boat containing several grams of precipitated SnO_2 was placed in the reaction tube in the hope of getting recrystallization of the added oxide. No change was observed in the contents of the alundum boat, but at the end of the experiment a few milligrams of colorless, transparent needlelike crystals were found deposited on one end of the boat. Iodimetric analysis of a small sample gave 95.8 ± 5 pct SnO_2.

Since there has been some disagreement in the literature as to the crystal structure of artificial stannic oxides,[5, 8, 9, 10] a brief X ray study was made of the needlelike crystals formed at 1000°C. Photographs were taken on the single-crystal rotational and the Weissenberg goniometric cameras in the Metallurgy Department X ray laboratory. From this work it was found that the crystals were orthorhombic, with the following lattice constants:

$a = 2.66$ A; $b = 4.81$ A; $c = 5.84$ A. These results confirm Daubree's[8] crystallographic observations of a hundred years ago that stannic oxide was dimorphous. Subsequent workers[8, 9, 10] disputed the existence of the orthorhombic variety and no mention of it was found in recent literature. Accordingly, we believe our measurements of the lattice constants represent the first X ray study of this form of SnO_2.

Our work confirms the feasibility of preparing crystalline SnO_2 by reaction of $SnCl_4$ and H_2O but shows also that considerable further experimentation will be necessary before satisfactory yields of high-purity crystals can be reproduced. By controlling the conditions it appears that either the usual tetragonal cassiterite or an unusual orthorhombic stannic oxide can be made.

Crystallization from Borax Melts: Fair yields of high-purity tetragonal cassiterite suitable for flota-

tion tests were obtained by the borax-crystallization procedure. Tin metal (c.p. reagent) was converted to dioxide by treatment with dilute nitric acid followed by ignition of the washed stannic acid. Borax (c.p. reagent) was fused in platinum to obtain borax glass. Mixtures of the dioxide and the borax glass containing from 5 to 25 pct dioxide were fused in platinum and then cooled by various procedures.

Table I. Crystallization of Cassiterite from Borax Melts

	Test *A*	Test *B*
Per cent SnO_2 in melt	15	15
Temperature of fusion	1375°C	1200°C
Time at fusion temperature	14 hr	14 hr
Method of cooling	Cooled in furnace to 1000°C, held for 6 hr, then cooled to room temperature in furnace	
Approximate crystal size	2-20 microns	1-5 microns

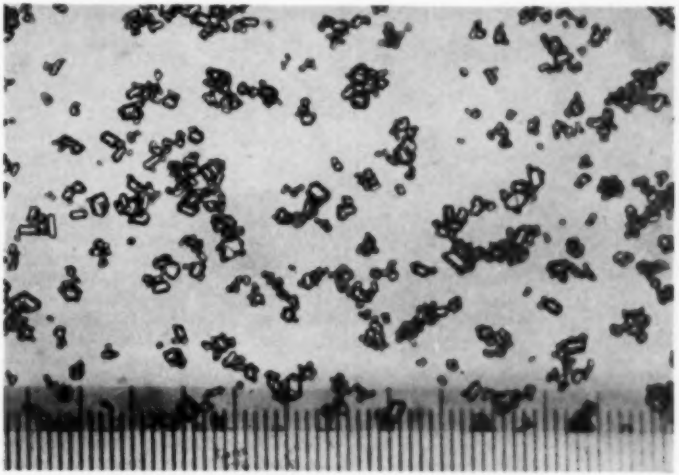


Fig. 1—Artificial cassiterite crystallized from borax melts.

One division equals ten microns.

The borax was separated by water-leaching the solidified melt. The cassiterite crystals were further cleaned with HCl, washed, and stored under water. Data for two typical preparations are summarized in table I. Test *A* represents the procedure finally used in preparing a stock of cassiterite for flotation tests.

Under the microscope the artificial cassiterite is colorless and appears identical with natural cassiterite, even showing the characteristic twinning of the natural variety (fig. 1). The powder in mass is white in color, in contrast to the brownish color of the cleaned natural cassiterite. Chemical analysis gave 99.8 pct SnO_2.

Powder diffraction patterns of the artificial and natural cassiterites were compared and found identical using the Debye-Scherrer camera. Also Phragmen diffraction patterns of the artificial material were obtained. From these, the lattice constants were calculated and compared with Vegard's[11] data for natural cassiterite, with the following results:

	Artificial	Natural (Vegard)
a	4.739 Å	4.72 Å
c	3.186 Å	3.17 Å
$\frac{c}{a}$	0.6714	0.6723

A further study of the artificial cassiterite, using the Norelco X ray spectrometer to obtain quantitative measurements of line intensities, showed close agreement of relative line intensities with the calculated values for natural cassiterite.

Details of the various X ray data and calculations discussed above are available in the original thesis from which this paper is abstracted.

Cassiterite Flotation

Vacuum-flotation tests were made with about 0.8 g of 2 to 20 micron artificial cassiterite per 100 ml pulp in each test. Critical pH values were determined for oleic acid additions from 0.28 up to 290 mg per liter. Exploratory tests were also made with $BaCl_2 \cdot 2H_2O$ (50 mg per liter) and $CaCl_2$ (41 mg per liter) added to the pulp. The data are plotted in fig. 2.

Cassiterite floats readily without activation over a wide pH range. Both a lower and an upper critical pH were found, with flotation occurring over the entire range in between. The lower critical pH decreases with increase in added oleic acid, from about pH 7 with 1 mg oleic acid per liter down to pH 2 with about 300 mg oleic acid per liter. The data approximate a straight line of slope —0.5 on the log-log plot, the line in fig. 2 following the relation:

$$\frac{(\text{Critical } H^+ \text{ conc.})}{(\text{HOl addition})^2} = 1.4 \times 10^4$$

when the units of both quantities are mols per liter. The deviation of the data from this relation below 1 mg oleic acid per liter is readily accounted for, since in this range of collector addition a large proportion of the collector may be on the mineral so that quantity added is no longer a measure of quantity in solution.

The flotation of cassiterite with oleic acid at pH values as low as 2 and 3 was unexpected in the light of previous experience in the flotation of Bolivian tin ores. Additional vacuum-flotation tests with cleaned natural cassiterite checked the results with the artificial cassiterite. As a further check several flotation tests were carried out on larger quantities of less carefully prepared natural cassiterite and

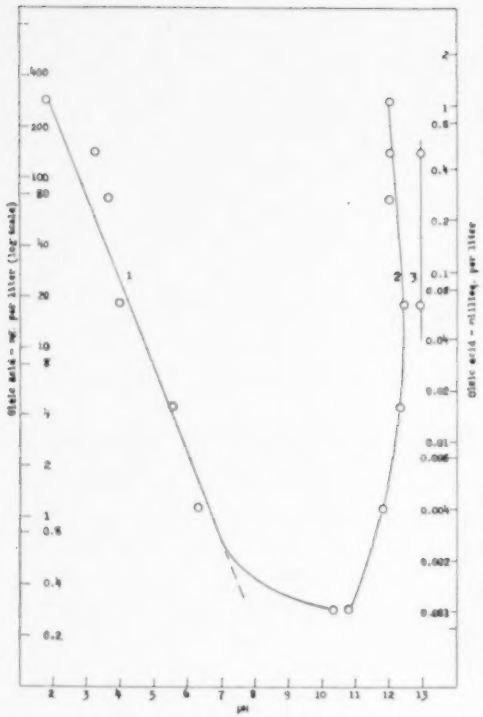


Fig. 2—Soap flotation of cassiterite.

Flotation occurs under conditions between lower and upper critical pH curves.
Curve 1, lower critical pH: in presence and absence of activators.
Curve 2, upper critical pH, no activator.
Curve 3, upper critical pH, with 41 mg $CaCl_2$ per liter. No upper critical pH found with 50 mg $BaCl_2.2H_2O$ per liter.

cassiterite-quartz mixtures, using standard grinding and flotation procedures and the Fagergren 500-g cell. In these larger-scale tests the cassiterite was floated with oleic acid at pH values down to 2. In one test on 500 g of a 1:1 mixture at pH 3, 0.39 lb oleic acid per ton gave 97.5 pct recovery of tin in a rougher float assaying 74.1 pct Sn.

The decrease in lower critical pH with increasing collector addition contrasts with the previously reported behavior of quartz activated with Ba^{++}, Ca^{++}, Al^{+++}, or Fe^{+++}. For activated quartz, increasing collector increased the lower critical pH, and excess collector tended to depress the quartz, presumably by deactivating it. The sharply contrasting behavior of the cassiterite and the activated quartz on increasing the collector argue against an explanation of cassiterite flotation in terms of accidental activation. However, we have been unable to develop an explanation of the chemistry of cassiterite flotation which will account for the observed relation between collector addition and lower critical pH.

The upper critical pH remained in the pH range from 11 to a little over 12, substantially constant over the 1000-fold range of collector addition tested. The upper critical pH was found by approach from the low pH side, and was irreversible in that nonflotation persisted to near neutrality when the pH was dropped from a high value. This phenomenon calls for further study.

Ba^{++} and Ca^{++} had no effects on the lower critical pH, indicating absence of activation in acid pulps. However, in alkaline pulps the Ba^{++} eliminated the upper critical pH entirely while the Ca^{++} raised the upper critical pH by substantially a full unit. All these effects parallel the behavior of Ba^{++} and Ca^{++} activated quartz. Activation of cassiterite by Ca at pH's in the vicinity of 12 was observed previously in the flotation testing of Bolivian tin ores.[1]

Effect of Alizarin Dyes: Vacuum-flotation tests were conducted with varying quantities of alizarin, alizarin red, and quinalizarin and the following activator-collector combinations:

Mg per Liter		
Oleic Acid	$BaCl_2.2H_2O$	$CaCl_2$
18.05	0	0
18.05	50	0
18.05	0	23.5

Lower and upper critical pH values for these tests are plotted in fig. 3, with pH values as abscissas and dye concentrations (log scale) as ordinates.

All the curves are of similar shape, showing that all three dyes act as depressing agents for cassiterite both in the absence of an activator and in the presence of Ba^{++} and Ca^{++}. In general, as dye concentration is raised, the flotation range between lower and upper critical pH narrows until a dye concentration is reached above which flotation is not obtained at any pH.

In the absence of an activator, 200 or 300 mg per liter of any one of the three dyes was required to secure complete depression of cassiterite over the entire pH range. Such concentrations of dye correspond roughly in magnitude to a pound or so of dye per ton under ordinary flotation conditions. Moreover, these quantities of dye are two or three orders of magnitude greater than would be needed to film the cassiterite monomolecularly. Clearly, unactivated cassiterite is not depressed easily with small dye additions, and this may prove advantageous.

Three of the curves involving the activator-dye combinations barium-alizarin red S, barium-quinalizarin, and calcium-quinalizarin showed marked enhancement of the depressing action of the dye through the presence of the alkaline-earth cation. For example, in fig. 3*b* it can be seen that complete depression at all pH values was obtained with 50 mg $BaCl_2 \cdot 2H_2O$ per liter and just over 10 mg alizarin red S per liter, whereas without the barium over 200 mg alizarin red S per liter was required for complete depression. The role of the barium in aiding the depression of the cassiterite appears analogous to its activating role in other systems, where it couples the collector to the mineral. However, in this system the barium couples the dye instead and thus assists depression. Pending further study and clarification, we have labeled this phenomenon "depression-sensitization" and the barium a "depression-sensitizer."

The use of barium, calcium, or lead to improve depression was reported previously, as follows:[1] "Added at first to aid in cassiterite activation, these ions proved more helpful in siderite depression." The observations made in the earlier work parallel

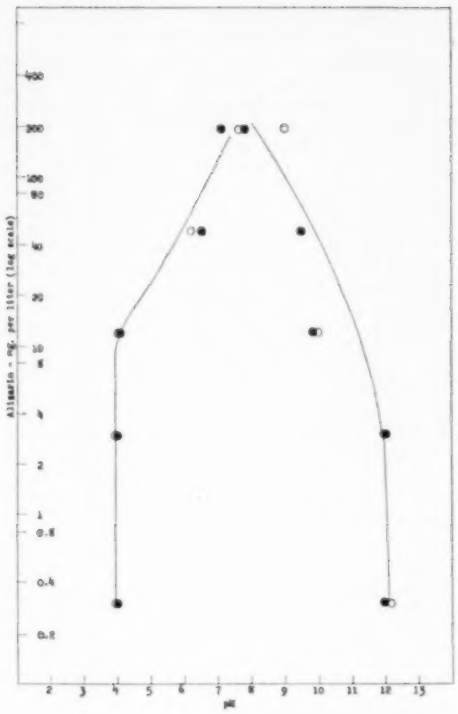


Fig. 3*a* (top left)—Effect of alizarin and $BaCl_2$ on soap flotation of artificial cassiterite.

Flotation occurs under conditions between lower and upper critical pH curves, nonflotation outside and above.
Blacked-in circles, no metal salts. Circles, 50 mg $BaCl_2.2H_2O$ per liter.

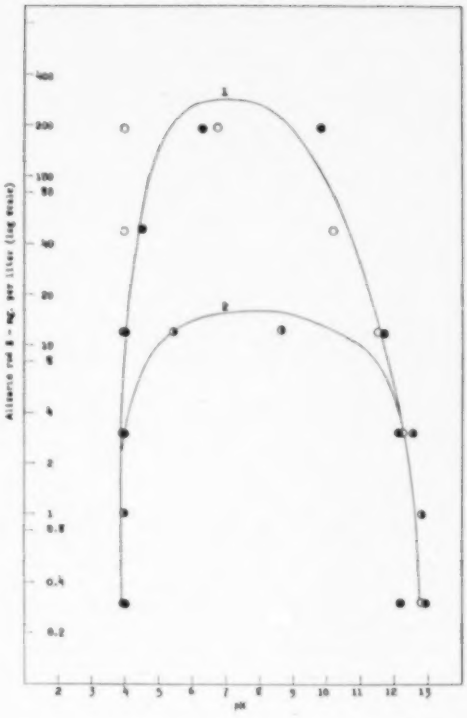


Fig. 3*b* (top right)—Effect of alizarin red S, $CaCl_2$, and $BaCl_2$ on flotation of artificial cassiterite.

Flotation under conditions inside curve, nonflotation outside.
Curve 1, no metal salt, and 23.5 mg $CaCl_2$ per liter.
Curve 2, 50 mg $BaCl_2.2H_2O$ per liter.

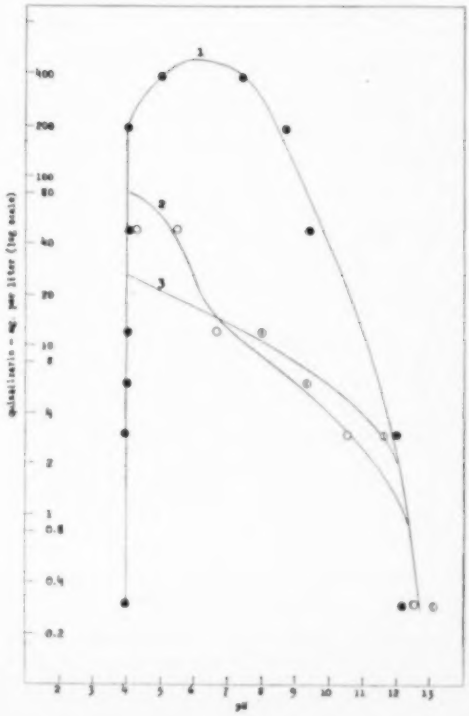


Fig. 3*c* (right)—Effect of quinalizarin, $CaCl_2$, and $BaCl_2$ on flotation of artificial cassiterite.

Flotation under conditions inside curve, nonflotation outside.
Curve 1, no metal salts.
Curve 2, 23.5 mg $CaCl_2$ per liter.
Curve 3, 50 mg $BaCl_2.2H_2O$ per liter.

in some respects the "depression sensitization" phenomena discussed above, but they were made in a much more complex system. We suspect the depression-sensitization to be a fairly common occurrence.

Fluorite Flotation

The critical-pH data for fluorite flotation with variable collector addition are plotted in fig. 4. Like unactivated cassiterite, fluorite floats over a wide pH range and wide range of oleic acid concentrations. Also, the trend of decreasing lower critical pH with increasing collector concentration is repeated for fluorite. In the case of fluorite, however, the straight line drawn through the lower, critical-pH data has

a slope of —1.0 and corresponds to the relation:

$$\frac{(\text{critical } H^{+} \text{ conc.})}{(\text{HOl addition})} = 13$$

when (H^{+}) and (HOl) quantities are expressed as mols per liter.

Like Ca-activated quartz and cassiterite, fluorite shows an upper critical pH. However, at high-collector concentrations the upper pH limit decreases so that with several hundred milligrams oleic acid per liter the fluorite does not float in alkaline pulps.

The effects of alizarin, alizarin red S, and quinalizarin on the flotation of fluorite with a fixed collector addition (18 mg HOl per liter) are shown in fig. 5. The critical-pH curves are similar to those for Ca-activated cassiterite. With both Ca-activated cassiterite and fluorite, a quinalizarin addition of about 100 mg per liter was required for depression over the whole pH range, whereas several hundred milligrams of alizarin or alizarin red S were required. However, at pH values above 9, the alizarin appears as effective as quinalizarin, in that fluorite is depressed with 10 mg, or less, dye per liter. From these data, the depression of fluorite with moderate addition of alizarin or quinalizarin at pH values above 9 appears to have practical possibilities. However, these possibilities might be illusory because of the relatively high water solubility of fluorite and because Ca-activation will then make other minerals behave like fluorite.

Reviewing data for both cassiterite and fluorite, there are strong indications of specific depressing actions for the combinations calcium-quinalizarin, barium-quinalizarin, and barium-alizarin red S, and indications of specificity in alkaline pulps for the combination calcium-alizarin. On the other hand Ca did not act as a depression-sensitizer with alizarin red S, and Ba did not cooperate with alizarin.

Effect of Alizarin Dyes on Flotation of Ba-activated Quartz

The previous work on flotation of Ba-activated quartz showed the following: (1) with oleic acid added in quantities up to stoichiometric equivalence to barium, lower critical pH values were near and just below neutrality; (2) with a large stoichiometric excess of oleic acid, much higher pH's (11 to 13) were required to obtain flotation of quartz. Thus, the principal need for using reagents to depress Ba-activated quartz will be in systems containing barium in some excess or at best only a little under stoichiometric equivalence with the oleic acid. Accordingly, the four activator-collector combinations given in table II*A* were selected for the tests with alizarin dyes. With each of these combinations, the dye addition was varied stepwise from 0.3 to 800 mg per liter, and the critical pH was determined at each step.

In each series of tests the behavior on adding dye was the same: Small additions of dye had no effect on critical pH, but as the dye concentration was increased a critical dye concentration* was reached above which the quartz ceased to float at all pH values. In view of the large amount of ground to be covered, large steps in dye concentration were taken between flotation tests, so that the critical ranges of dye concentration were determined only very roughly. Results are summarized in table II*B*.

* Actually a critical range of dye concentrations, as the transition was not abrupt.

Table II. Effect of Dyes on Flotation of Ba-Activated Quartz

A. Activator-collector Combinations

Series No.	$BaCl_2.2H_2O$		Oleic Acid		Excess, Mieq. per Liter		Lower Crit. pH, without Dye
	Mg per Liter	Mieq. per Liter	Mg per Liter	Mieq. per Liter	Ba	HOl	
I	3	0.025	20	0.071		0.046	7.0
II	50	0.409	120	0.425		0.016	6.9
III	50	0.409	40	0.142	0.267		6.5
IV	300	2.456	200	0.708	1.748		6.5

B. Critical Ranges of Dye Concentration

Series No.	Dye Concentrations, Mg per Liter							
	Alizarin		Alizarin Red S		Quinalizarin		Anthracene Blue	
	Float[a]	Nonfloat[b]	Float	Nonfloat	Float	Nonfloat	Float	Nonfloat
I	48	192	48	192	12	48	12	48
II	192	576	75	100	48	192	48	192
III	192	576	12	48	48	192	48	192
IV	192	576	48	192	48	192	576	768

[a] Quartz floats with lower critical pH not more than 1 or 2 units above critical value with no dye.
[b] No quartz flotation at any pH.

Obviously these data are too exploratory to give any detailed correlation, but the following points may be noted: (1) Large additions of all four dyes depress Ba-activated quartz. (2) The dye quantities required for depression are much in excess of the requirements to form a monomolecular film on the quartz. (3) Alizarin is the least effective depressant.

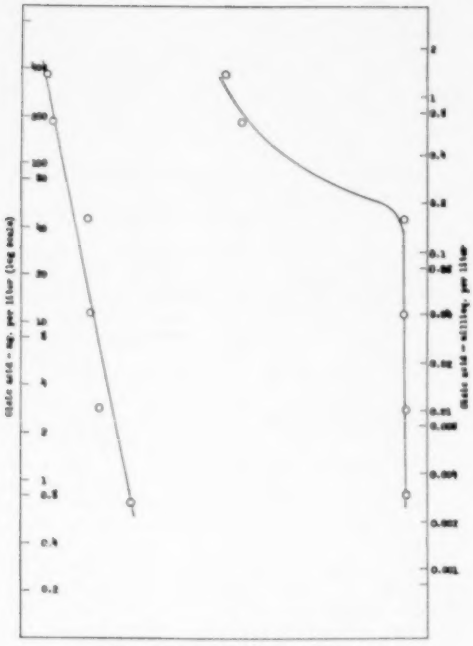


Fig. 4—Soap flotation of fluorite.
Flotation occurs between lower critical pH at left and upper critical pH at right.

This correlates with the finding that Ba did not act as a depression-sensitizer for the depression of cassiterite with alizarin. (4) Alizarin red S and quinalizarin in concentrations on the order of 100 mg or more per liter depress barium-activated quartz. (5) Anthracene blue was an effective depressant only for the lower barium additions.

Selective Flotation of Cassiterite, Fluorite, and Quartz in Artificial Mixtures

One of the reasons for working with cassiterite, fluorite, and quartz was that these three minerals occur together in Colquiri tin ore and a great number of flotation tests had been made in attempting to separate them from each other.[1] Accordingly, as one step in bridging the space between the pure-mineral studies and the earlier ore testing, a few flotation tests were made on artificial mixtures. It was found that the deslimed cassiterite, quartz, and fluorite were readily distinguishable visually in the 100 ml graduates, so qualitative tests were made in the vacuum-flotation apparatus, following the same procedure in conditioning, reagent addition, and flotation as that used in the pure-mineral tests.

The plan followed in this part of the work was to study the pure-mineral data and find conditions of pH and reagent concentration which would give the desired separation, on the *assumption* that the minerals would behave independently of each other. Then a vacuum flotation was attempted under the chosen conditions. The results are only indicative and should be followed up with quantitative-flotation tests on a larger scale, in thicker pulps, with slimes present, etc.

Cassiterite-quartz: In the absence of activators, quartz does not float with oleic acid while cassiterite floats over a wide pH range. In the presence of Ba^{++} and Ca^{++}, cassiterite will float in acid pulps while quartz will not. These expectations were confirmed by vacuum-floating cassiterite from quartz. Also, as already described, larger-scale tests in a Fagergren cell gave good metallurgical results in floating cassiterite from quartz in acid pulps. Evidently cassiterite did not supply activating ions to the quartz under the conditions of our tests.

Reference to data in table II and in fig. 3*b* and 3*c* indicated that in the presence of Ba and at moderately high pH values cassiterite could be depressed with small additions of alizarin red or quinalizarin, too small to depress the quartz if barium were in stoichiometric excess over oleic acid. After a few trials, quartz was vacuum-floated from cassiterite with each of the following combinations:

A	
$BaCl_2 \cdot 2H_2O$	50 mg per liter
Oleic acid	18 mg per liter
Alizarin red S	40 mg per liter
pH 10.5	
B	
$BaCl_2 \cdot 2H_2O$	50 mg per liter
Oleic acid	18 mg per liter
Quinalizarin	50 mg per liter
pH 10	

In both these systems, the barium acted as a depression-sensitizer for cassiterite and as an activator for quartz. With somewhat higher dye concentrations both minerals were depressed, and with-

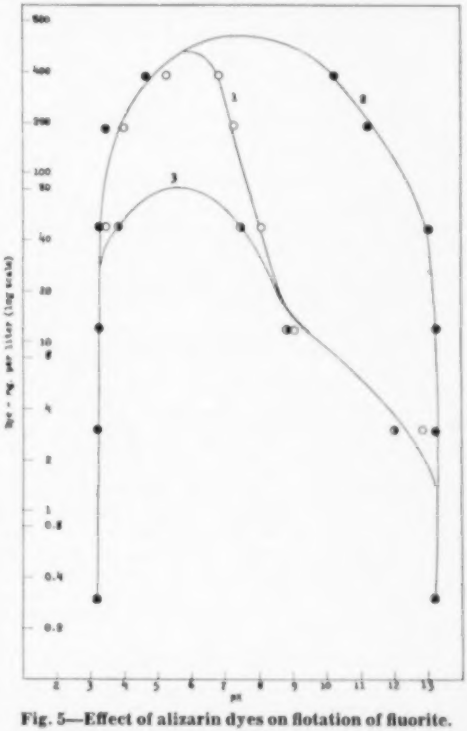


Fig. 5—Effect of alizarin dyes on flotation of fluorite.
Flotation under conditions inside curve, nonflotation outside.
Curve 1, alizarin
Curve 2, alizarin red S.
Curve 3, quinalizarin.

out dye both minerals floated. Presumably, though unfortunately it was not tried, omission of barium would have resulted in flotation of cassiterite from quartz.

Cassiterite-fluorite: Examination of the data for cassiterite and fluorite (fig. 3*b* and 5) indicated that fluorite should float from cassiterite at pH 11 to 12 with 18 mg oleic acid and 100 mg alizarin red S per liter and at pH 6 to 10 with 18 mg oleic acid and 300 mg alizarin red S per liter. These separations were confirmed qualitatively.

Using alizarin red S as depressor, $BaCl_2$ was found (fig. 3*b*) to act as a depression-sensitizer for cassiterite while $CaCl_2$ did not so act. Also a high concentration of alizarin red was required to depress fluorite (fig. 5). Thus from the pure-mineral results it appeared possible to float fluorite from cassiterite using barium as a depression-sensitizer for the cassiterite. A selective float of fluorite from cassiterite was made under the following conditions:

$BaCl_2 \cdot 2H_2O$	50 mg per liter
Oleic acid	18 mg per liter
Alizarin red S	60 mg per liter
pH 9.2	

The pure-mineral data suggested no procedure for floating cassiterite from fluorite with the reagents under investigation.

Quartz-fluorite: Fluorite was floated away from quartz by operating at a pH too low for Ca-activation of the quartz. The test was made at pH 5.6, with 50 mg oleic acid per liter.

Cassiterite-fluorite-quartz: Quartz and fluorite were floated from cassiterite with the following combination:

$BaCl_2 \cdot 2H_2O$	50 mg per liter
Oleic acid	18 mg per liter
Alizarin red S	40 mg per liter
pH 11	

Summary and Conclusions

Critical-pH determinations using a small-scale, vacuum-flotation technique were made for the soap flotation of cassiterite and fluorite. Conditions for flotation and nonflotation were determined for varying additions of oleic acid alone and for pulps containing oleic acid with various concentrations of alizarin dyes. The dyes tested were alizarin, alizarin red S, quinalizarin, and anthracene blue W.R.S., which all have the same structure but differ in the number of substituent groups. Exploratory tests were made of the flotation of cassiterite, fluorite, and quartz using oleic acid as collector, alizarin dyes as depressors, and Ba or Ca as auxiliary modifiers.

Pure cassiterite was prepared for flotation by crystallization from borax, tin oxide melts. A detailed X ray investigation showed this synthetic material to be crystallographically identical with natural cassiterite. Attempts to prepare cassiterite by reaction of $SnCl_4(g)$ and $H_2O(g)$ at high temperatures were only partly successful, and in one experiment yielded an orthorhombic variety of tin dioxide.

The main conclusions are summarized below:

1. Unactivated cassiterite and fluorite both float over wide ranges of oleic acid concentration and wide pH ranges. For a given collector concentration, flotation occurs at all pH values between a lower critical pH on the acid side of neutrality and an upper critical pH well on the alkaline side.

2. The lower critical pH decreases and the pH range of flotation widens with increase in collector concentration, for both cassiterite and fluorite. This contrasts with the behavior of activated quartz, in which increasing collector raises the lower critical pH and narrows the pH range of flotation. With moderate collector additions, cassiterite floats in pulps as acid as pH 2 or 3.

3. Cassiterite is activated by Ba and Ca in alkaline pulps, giving an increase in upper critical pH over the values obtained in the absence of these ions.

4. In concentrations of a few hundred milligrams per liter, the alizarin dyes depress cassiterite, fluorite, and quartz over the whole pH range, both in the presence and in the absence of Ba and Ca. The dye additions for complete depression are of a higher order of magnitude than the requirements to form monomolecular films on the minerals.

5. The critical dye concentrations for depression are markedly decreased in some systems by addition of a metal salt. Thus, Ba specifically aids in depressing cassiterite with alizarin red and quinalizarin while Ca aids in depressing cassiterite with quinalizarin and alizarin. These effects are chemically parallel to activation, and may be important in other systems.

6. With respect to the effects of dyes and to the magnitude of upper critical pH, Ca-activated cassiterite behaves similarly to fluorite while Ba-activated cassiterite behaves like Ba-activated quartz.

7. Further, more detailed study of the depressing actions of the various substituted alizarin dyes, alone and in combination with various metal salts, should lead both to important fundamental information on flotation chemistry and to useful improvements in the selective flotation of nonsulphide minerals.

References

[1] A. M. Gaudin, R. Schuhmann, Jr., E. G. Brown, F. Ergunalp, and R. T. Hukki: Making Tin Flotation Work. *Eng. and Min. Jnl.* **147** (Oct. 1946) 54-59; (Nov. 1946) 72-74; (Dec. 1946) 68-72; **148** (Jan. 1947) 84-87; (March 1947) 70-72.

[2] R. Schuhmann, Jr. and B. Prakash: Effect of $BaCl_2$ and Other Activators on Soap Flotation of Quartz. *Trans.* AIME, **187**; *Min. Eng.* 1950.

[3] A. Daubree: Researches on the Production of Artificial Crystalline Minerals, Especially the Oxides of Tin and Titanium and of Quartz. *Compt. rend.* (1849) **29**, 227.

[4] G. Wunder: Stannic and Titanic Compounds Crystallized from Fluxes. *Jnl.* Prakt. Chem. (1870) **2** (2) 206; (1871) **4** (2) 340.

[5] A. Knop: On Some Substances Crystallized from Microcosmic Salt and from Borax. *Ann. Ch. Pharm.* (1872) **158**, 36-58.

[6] K. K. Kelley: Contributions to the Data on Theoretical Metallurgy. U. S. Bur. of Mines, *Bulls.* 371, 383, 407 and 434.

[7] D. R. Stull: Vapor Pressure of Pure Substances. *Ind. and Eng. Chem.* (1947) **39**, 517-550.

[8] H. St. C. Deville: The Production of Stannic Oxide and Rutile. *Compt. rend.* (1861) **53**, 161.

[9] P. Groth: Chemische Krystallographie. Vol. 1, 84, 96 (1906) Leipzig.

[10] A. Arzruni: Artificial Cassiterite. *Ztsch. Kryst. Min.* (1895) **25**, 467.

[11] L. Vegard: Results of Crystal Analysis. *Phil. Mag.* (1916) **32** (6) 65; (1926) **1** (7) 1151.

[12] G. Gutzeit: Chelate-forming Organic Compounds as Flotation Reagents. *Trans.* AIME (1946) **169**, 272; *Min. Tech.* (Nov. 1946) TP 2077.

Laboratory Control in Coal Washing and Drying Plants

by James J. Merle and Richard A. Mullins

Systematic sampling and analysis in coal-washing plants results in product control and economical operation. A well-organized laboratory system reduces operating costs and increases sales if the operating and sales companies make full use of information it supplies. The operating cost of a control laboratory is less than 1 pct per ton of coal produced.

History

THE system of laboratory control as practiced by the Ayrshire group of mines was begun with the construction and organization of the first laboratory in conjunction with the completion of its first washery in 1941. The primary purpose of this laboratory was to maintain a check on the quality of the coal produced from the washing plant. The laboratory was equipped to determine proximate analyses, float-and-sink tests, and screen analyses, and was staffed by a chemist, an assistant, and a technician.

JAMES J. MERLE and RICHARD A. MULLINS, Members AIME, are Assistant Preparation Manager and Chief Chemist, respectively, Ayrshire Collieries Corp. and Subsidiaries, Danville, Ill.

Joint AIME-ASME Fuels Conference, French Lick, October 1949.

TP 2855 F. Discussion (2 copies) may be sent to Transactions *AIME before June 30, 1950. Manuscript received Aug. 22, 1949.*

Soon it became apparent (1) that product control could be accomplished, (2) that a substantial reduction in operating costs could be effected by close control of coal losses in the rejects, and (3) that information furnished by the laboratory was of continuous value to the operating and sales companies. Consequently the laboratory function was expanded to supply them with additional data as required.

As the parent company expanded and new mines were added, control laboratories were established at each mine equipped with washeries, and a central laboratory was maintained at one of the mines that was located equally convenient to all of them.

Purpose and Use of Laboratory Control

A well-planned control laboratory assures production of a uniform, high-quality product. Whenever coal of substandard grade is loaded inadvertently, the sales company can be informed and the proper channel of distribution made. Conversely only constant and strict laboratory supervision can insure proper production of the various grades.

Knowing the product, the producer can keep out of many customers' arguments that may be both awkward and expensive. Double checking between customers and mine laboratories have solved many disputes.

Some consumers insist on buying coal on the analysis basis only, with penalties for substandard coal and premiums for coal above normal quality. A substantial percentage of the coal sold by the Ayrshire group is of this nature. The usual procedure is for the customer to sample and analyze the coal as it is unloaded at the plant, and the mine laboratory samples it as it is loaded at the mine for subsequent analysis by the central laboratory. Only the unloaded moisture is considered, rather than the average of mine and plant moisture, and the buyer sends duplicate samples to the central mine laboratory for this determination. The average of the two analyses determines the price of coal at the mine. In this particular case, the laboratory plays an important part in increasing realization for two reasons: (1) every attempt is made to maintain plant efficiency and product quality as high as possible, (2) check on analyses and sampling by the buyer or seller.

Relatively simple determination such as screen analyses detect wear that could prevent production of off-size coal objectionable to the customer and result in lowered realization because of higher-priced grades being mixed with lower-priced grades. Similar information on individual units in a washery quite often results in data leading to changes that will result in more economical operation.

Economics of Laboratory Control

Value of a Control Laboratory: The actual assets of a laboratory may be enumerated as follows:

1. Analyses and services rendered by the laboratory to the operating company, sales company, and customers.

2. The laboratory works closely with the engineering department in determining purchase or rejection of new coal lands.

3. Increase in realization and securing maximum recovery by reducing plant losses to a minimum. The washing plants of the Ayrshire group alone reject more than one-half million tons of refuse yearly not including slurry. It has been the experience of the company that the difference in coal lost in the refuse between close control and poor control totals many tons yearly, and at the dollar value per ton of coal the profit or loss can be substantial. It is also significant to note that even a one per cent reduction or increase in coal loss in the refuse would mean much to the income of the mine. Moreover reduction in coal losses usually means that a plant must be operated with increased efficiency. Therefore the quality of the washed product is not reduced by the addition of float coal that was formerly rejected, but is actually improved because of the increased efficiency.

Close scrutiny of the daily slurry samples and their analyses will determine when it is economical to change screens. Many tons of coal are lost in the slurry because the usual practice too often is not to change screens until they are completely worn out. Often the loss of coal from one day's operation will pay for a set of expensive stainless steel screens, since an increase in opening from ½ to 1 mm may double the percentage of slurry, which may be an increase of 30 tons per hour in a fairly large plant.

Operating Costs: The actual costs of a laboratory system may be summarized as follows:

1. Control laboratories. Labor cost is less than $0.01 per ton.

2. Central laboratory. Labor cost is $0.003 per ton of washed coal produced. The costs of a central laboratory are prorated according to the total tonnage of washed coal produced by the Ayrshire group.

3. Costs of material used in relation to cost per ton is negligible in comparison to the labor cost.

It can be seen from the foregoing that the entire laboratory costs are more than repaid, and some laboratory expense would have been necessary under any circumstances for analyzing washed coal.

Function of the Control Laboratory

Each of the mechanical cleaning plants is provided with a control laboratory staffed with two men: a technician and a technologist.

The duties of the technician are:

1. Sample hourly every size of washed coal produced.

WEATHER Fair
TEMPERTURE 72° to 93° F

AYRS

DAILY LOADING, RECOVERY, OPERATING AND LABORATORY RECORD

RAW COAL INPUT — REMARKS

	Condition	Trucks	Tons
Trucks @ 34.4 Tons/Truck	127	4363	Raw coal good all day

TONS PER HOUR 626

WASHED COAL AND BY-PASSED

	Cars	Tons	Total per Month
Railroad Cars Loaded	56	2454	
By-Passed to Trucks		637	
By-Passed to Heat Dryers		4	
TOTAL WASHED		3556	
Refuse		593	593
Sludge		174	174
TOTAL		4363	

Time Operating 6 HR 51 MIN — Weightometer PM 330 TR
Time Loss 10 MIN — Weightometer AM 28 TR
TOTAL TIME 7 HR 15 MIN — TOTAL RAW COAL 4363

OPERATING TIME LOSS

From	To	Min	Cause of Delays
8:31	9:05	4	Hopper empty
10:10	10:28	3	Power failure
2:36	3:18	2	Car under No. 1 track
3:18	3:21	1	Hopper empty
		10	

WASHER ADJUSTMENT LOG

Treating	#1-6"+0	#2-6"+0	Middlings
Impulse Adjustments	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
A Air Valve Quadrant	3½ 2½ 1½ 1½ 2	3 2½ 1½ 1 2	3½ 2 1½ 1 1
W Water Valve Stem Extension	3½ 3 2½ 1 1	3½ 3 2½ 1½ 1½	2 2 1½ 1½ 1½
V Ecc Rods from Standard	5 5 5 5 5	5 5 5 5 5	5 5 5 5 5
C Partition Plate	14 15 14 14 14	15 14 14 14 14	21 20 20 20 20
Ecc Shaft	#6 R R R	#6 R R R	#6 R R R

Ejection Adjustments	#1-6"+0 Primary	#1-6"+0 Secondary	#2-6"+0 Primary	#2-6"+0 Secondary	Middlings Primary	Middlings Secondary
D Depth Scale Setting	8 ¾	9	8 ¾	8 ¾	7 ¾	6
R Float Submergence Scale, Reading WATER	19	19	19	19	19	18 ½
R Beam Reading Ash (Decimal)	182	175	169	126	148	192
O Orifice Rod Extension (Inches)	7 ¾	7	7 ¾	7	3	3
W Wear Rod Extension (Inches)		2 ¾				1 ¾
Receiver Pressure		8 ¾		7 ¾		7
Idle Water Head		16 FT		16 FT		16 FT

Thomas Nightengale
Plant Foreman

WASHER DATA	Tons	Total Moisture	% Ash, Dry	Float at 1.50 Sink at 1.50 Wt %	Float at 1.50 Ash %	Sink at 1.50 Wt %	Sink at 1.50 Ash %
Raw Coal Input	4363	14.1	17.2	82.9	6.2	17.1	62.1
Washed Coal output	3556	9.2	8.6	98.8	6.2	1.2	21.9
Refuse	593		62.9	1.8	4.7	98.2	64.6
Sludge	174		39.8	30.6	10.0	69.4	53.8

Yield, Dry Coal %	82.4
Qualitative Eff %	95.0
QUANTITATIVE Eff %	98.7
General Eff %	92.7
Loss of Coal in Refuse, Tons	10.7
Dry Sludge % Raw Coal	4.0
Dry Solid % Slurry Effluent	9.1
% Solids, Recirculating Water	5.7
Pct Recirculating Water	76

RHEO FINE COAL PLANT

	Washed Coal Wt %	Washed Coal Ash %	Refuse Wt %	Refuse Ash %
Float at 1.6	94.2	7.5	14.1	45.5
Sink at 1.6	5.8	93.5	85.9	69.1

HEAT DRYERS

Total Moisture %	
Feed	19.6
Product	12.7

CENTRIFUGAL UNIT

Total Moisture %	
Feed	33.9
Product	26.8

OIL TREATING

Oil Used-Gal	91
Tons Treated	11.7
Gal. Per Tons	1.49
Oil Stock	7091

Fig. 1—Chart of daily loading, recovery,

2. Prepare each sample for analysis. This includes primary crushing, riffling, and pulverizing the final sample to minus 100 mesh.

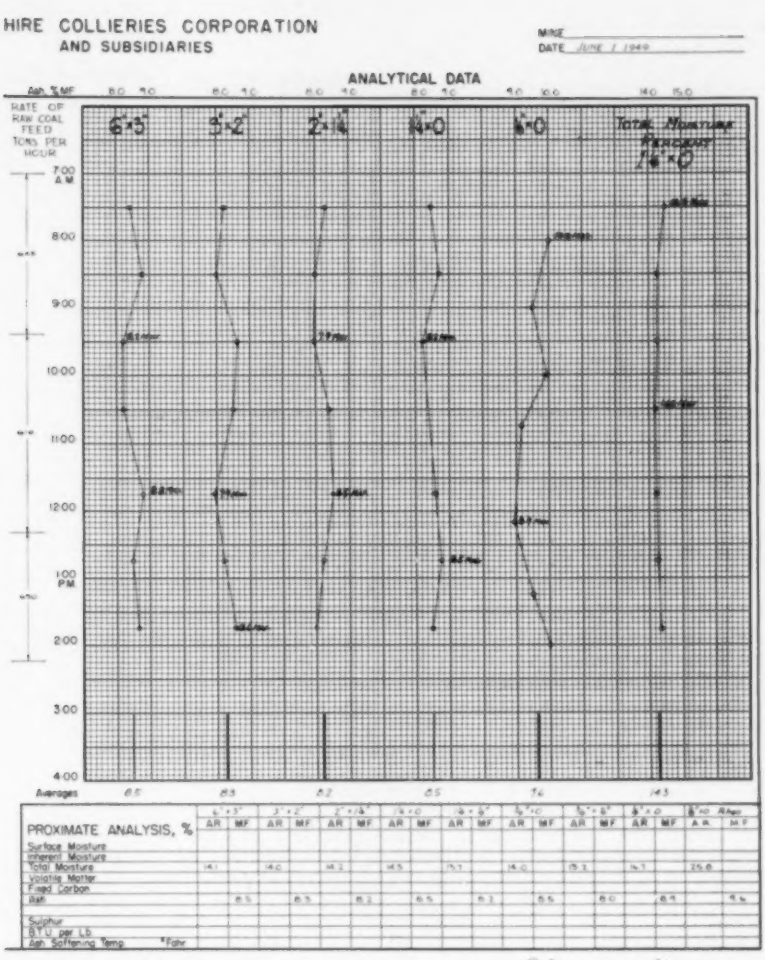
3. Sample the total plant refuse every hour. Determine the percentage of coal in the refuse on composite samples both morning and afternoon by float-and-sink methods. Delatesters are used at all of the operations.

4. Collect samples of washed coal for float-and-sink and screen tests. Float-and-sink tests are determined daily on the composite samples; screen analyses determined weekly on all grades produced.

5. Sample feed and product from centrifugal and thermal driers hourly for subsequent moisture determination on each daily composite.

6. Sample slurry, recirculating water and fine coal plant product and refuse for daily determinations. Some of the operators of individual plant units aid in the collection of samples.

7. Sample individual cars when necessary to check immediately for screen consist and ash con-



operating and laboratory record.

tent for coal orders requiring a product of definite specifications.

On idle days the technician aids the technologist in his work and thus in time acquires sufficient training and skill to become a technologist. All of the technologists employed by the company were trained and developed in this manner.

The duties of the technologist are:

1. To supervise and instruct the technician.

2. To determine the ash content of each of the washed coal graded, sampled, and prepared by the technician. By a modified procedure, these results are available about one hour after the sample is taken. The results are transmitted immediately by means of a Selsyn motor-generator set, with identical sending and receiving dials in the laboratory and washer floor in the plant. The laboratory and the washer floor are also connected for communication by telephone. Thus the operator can make any necessary changes in washer settings based upon information supplied by the laboratory.

3. To determine the moisture and ash on composite samples made up of portions of each of the hourly samples. These determinations are by approved ASTM methods and check closely the modified rapid method.

4. To make specific gravity analyses on the samples from the fine coal plant.

5. To prepare all reports, such as fig. 1.

6. To maintain a record of all preparation-plant maintenance, including all labor and material, that will be used to study plant operating costs and to promote changes that will increase plant efficiency.

Description of the "Daily Loading, Recovery, Operating and Laboratory Record" follows and a sample is shown in fig. 1.

1. The plant foreman is responsible for filling in the loading and operating section of the report. The raw coal tonnage is ascertained by weightometer, the washed coal tonnage is supplied by the weighmaster, and includes the number of railroad cars loaded and tonnage of washed coal bypassed to the

furnace bins and domestic truck bins. The tonnage of sludge is calculated from the percentage of solids in the daily slurry sample together with the known gallons per minute of slurry pumped. The latter is constant within close limits, but it is checked periodically. The refuse tonnage is by difference and the raw coal moisture is taken as the moisture of the largest size of washed coal produced. The moisture of the larger grades approximates the actual raw coal moisture which is checked periodically.

The washer operator keeps a record of operating lost time as well as the washer settings.

2. Table I gives the data from which the curves shown on fig. 1 were plotted:

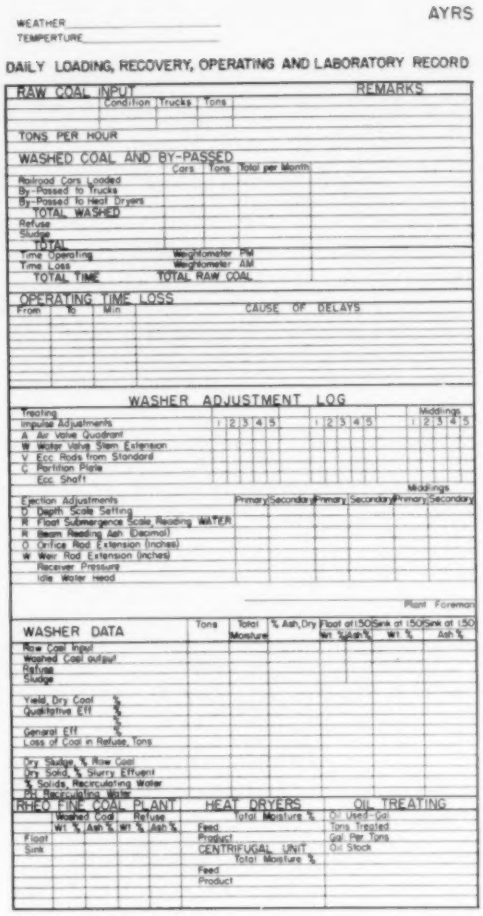
Table I. Dry Ash, Per Cent

Time	6x3 In.	3x2 In.	2x1¼ In.	1¼x0 In.	½x0 In. Rheo	Moisture, Pct 1¼x0 In.
7:30	8.4	8.2	8.3	8.4		14.5
8:00					10.0	
8:30	8.8	8.0	8.0	8.7		14.3
9:00					9.5	
9:30	8.2	8.6	7.9	8.2		14.3
10:00					9.9	
10:30	8.2	8.5	8.4			14.2
10:45					9.2	
11:45	8.8	7.9	8.5	8.6		14.2
12:10					8.9	
12:45	8.5	8.2	8.2	8.8		14.3
1:15					9.5	
1:45	8.7	8.6	8.0	8.5		14.4
2:00					10.0	
Average	8.5	8.3	8.2	8.5	9.6	14.3

The technologist plots the results of the hourly ash and moisture determinations, tabulates the daily composite ash and moisture results, specific gravity analysis of the washed coal, refuse and fine coal plant samples, and calculates and tabulates the data shown under "Washer Data" in fig. 1.

Because it is not considered economical to sample the raw coal daily, the raw coal data are ascertained by calculation. The data are accurate since the procedure is to combine, mathematically, the known components that make up the raw coal.

Below is the procedure used in calculating the "Washer Data":


WEATHER
TEMPERTURE
AYRS

DAILY LOADING, RECOVERY, OPERATING AND LABORATORY RECORD

RAW COAL INPUT — Condition, Trucks, Tons — REMARKS

TONS PER HOUR

WASHED COAL AND BY-PASSED — Cars, Tons, Total per Month

Railroad Cars Loaded
By-Passed to Trucks
By-Passed to Heat Dryers
TOTAL WASHED
Refuse
Sludge
TOTAL
Time Operating — Weightometer PM
Time Loss — Weightometer AM
TOTAL TIME — TOTAL RAW COAL

OPERATING TIME LOSS — From, To, Min. — CAUSE OF DELAYS

WASHER ADJUSTMENT LOG

Treating — Middlings
Impulse Adjustments 1 2 3 4 5 — 1 2 3 4 5 — Middlings 1 2 3 4 5
A Air Valve Quadrant
W Water Valve Stem Extension
V Ecc. Rods from Standard
C Partition Plate
Ecc. Shaft

Middlings
Ejection Adjustments — Primary, Secondary, Primary, Secondary, Primary, Secondary
D Depth Scale Setting
R Float Submergence Scale Reading WATER
R Beam Reading Ash Decimal
O Orifice Rod Extension (inches)
W Weir Rod Extension (inches)
Receiver Pressure
Idle Water Head

Plant Foreman

WASHER DATA — Tons — Total Moisture — % Ash, Dry — Float at 1.50 Wt. % — Ash % — Sink at 1.50 Wt. % — Ash %

Raw Coal Input
Washed Coal output
Refuse
Sludge
Yield, Dry Coal %
Qualitative Eff %
%
General Eff %
Loss of Coal in Refuse, Tons
Dry Sludge, % Raw Coal
Dry Solid, % Slurry Effluent
% Solids, Recirculating Water
Pct Recirculating Water

RHEO FINE COAL PLANT — Washed Coal: Wt. %, Ash %; Refuse: Wt. %, Ash %
Float
Sink

HEAT DRYERS — Total Moisture %
Feed
Product
CENTRIFUGAL UNIT — Total Moisture %
Feed
Product

OIL TREATING
Oil Used—Gal.
Tons Treated
Gal. Per Tons
Oil Stock

Fig. 2—Chart of screen analyses

$$\text{Yield, pct} = \frac{\text{washed coal output, tons} \times (100 - \text{washed coal moisture}) \times 100}{\text{raw coal input, tons} \times (100 - \text{raw coal moisture})}$$

$$= \frac{3{,}596 \times (100.0 - 14.2) \times 100}{4{,}363 \times (100.0 - 14.1)} = 82.4 \text{ pct}$$

$$\text{Raw coal float, wt pct} = \text{pct raw coal float in washed coal} + \text{pct raw coal float in refuse} + \text{pct raw coal float in sludge}$$

$$= \frac{82.4 \times 98.8}{100} + \frac{13.6 \times 1.8}{100} + \frac{4.0 \times 30.6}{100}$$

$$= 81.41 + 0.24 + 1.22 = 82.9 \text{ pct}$$

$$\text{Raw coal float ash, pct} = \frac{\text{pct raw coal float in washed coal} \times \text{washed coal float ash}}{\text{pct raw coal float}} + \frac{\text{pct raw coal float in refuse} \times \text{refuse float ash}}{\text{pct raw coal float}} + \frac{\text{pct raw coal float in sludge} \times \text{sludge float ash}}{\text{pct raw coal float}}$$

$$= \frac{81.4 \times 8.2}{82.9} + \frac{0.24 \times 14.7}{82.9} + \frac{1.22 \times 8.0}{82.9}$$

$$= 8.05 + 0.04 + 0.12 = 8.2 \text{ pct}$$

HIRE COLLIERIES CORPORATION
AND SUBSIDIARIES

MINE
DATE WEEK ENDING June 4 1949

ANALYTICAL DATA

Scr. % MF

SCREEN ANALYSES

6" × 3"		3" × 2"		2" × 1¼"		1¼" × 0	
Size	Wt %	Size	Wt %	Size	Wt %	Size	Wt %
Plus 6"	0.0	Plus 3"	3.0	Plus 2"	0.5	Plus 1¼"	3.0
6" × 4"	3.0	3" × 2"	44.3	2" × 1¼"	44.2	1¼" × ⅝"	24.9
4" × 3"	64.0	2" × 1¼"	1.5	1¼" × ⅝"	3.6	⅝" × ¼"	36.7
3" × 2"	2.2	1¼" × 0	0.6	⅝" × 0	1.0	¼" × ⅛"	13.2
2" × 0	9.7		100.0		100.0	⅛" × 0	12.0
	100.0						88.0

¼" × 4"		¾" × ¼"		⅛" × 0		¼" × 0	
Size	Wt %	Size	Wt %	Size	Wt %	Size	Wt %
Plus ¼"	1.8	Plus ¾"	1.2	Plus ⅛"	2.6	Plus ¼"	10.4
¼" × ⅛"	50.7	¾" × ¼"	61.3	⅛" × ¼"	36.9	¼" × ⅛"	44.5
⅛" × ¼"	44.2	¼" × ⅛"	36.0	¼" × ⅛"	23.4	⅛" × 0	45.1
¼" × ⅛"	1.9	⅛" × 0	0.7	⅛" × ¼"	17.8		100.0
⅛" × 0	1.4		99.0	⅛" × 0	17.3		
	100.0				100.0		

DUSTINESS INDEX

¼" × 4" STOKER COAL SAMPLED MAY 25, 1949

	Oil Treated @ 1.25 Gal/Ton	Untreated Coal
Index, Coarse Dust	2.0	22.5
Index, Fine Dust	1.2	1.5

TESTED June 3, 1949

Averages

PROXIMATE ANALYSIS, %	6" × 0		3" × 2"		2" × 1¼"		1¼" × 0		1¼" × ¼"		⅝" × 0		⅝" × ⅛"		¼" × 0		¼" × 0 Rhea	
	AR	MF	AR	MF	AR	MF	AR	MF	AR	MF	AR	MF	AR	MF	AR	MF	AR	MF
Surface Moisture																		
Inherent Moisture																		
Total Moisture	10.9		10.8		9.2		9.2		13.8		14.2		13.9		17.1		24.3	
Volatile Matter	40.1	46.5	40.6	46.9	40.6	47.5	40.5	47.2	40.7	47.5	40.9	47.1	41.1	47.4	38.8	44.8	33.4	46.2
Fixed Carbon	48.7	45.0	48.7	44.9	50.5	44.6	50.2	44.5	44.6	44.8	43.9	44.6	44.1	44.6	43.6	44.4	42.3	43.9
Ash	1.3	0.5	1.1	0.2	0.9	0.1	1.1	0.3	0.9	0.7	1.1	0.3	0.9	0.8	0.5	0.8	0.8	0.9
Sulphur	2.5	2.9	2.6	3.0	2.5	2.9	2.5	2.9	2.4	2.8	2.6	3.0	2.4	2.8	2.6	3.1	2.4	3.3
BTU per Lb	11425	13270	11473	13510	11457	13350	11411	13300	11490	13360	11411	13300	11466	13340	11098	13310	11406	12810
Ash Softening Temp °Fahr	2120		2175		2150		2150		2170		2140		2140		2185		2140	

and dustiness index tests.

Technologist

Chief Chemist

Raw coal sink, wt pct = 100 — raw coal float, wt pct

or, = pct raw coal sink in washed coal + pct raw coal sink in refuse + pct raw coal sink in sludge

$$= \frac{82.4 \times 1.2}{100} + \frac{13.6 \times 98.2}{100} + \frac{4.0 \times 69.4}{100}$$

$$= 0.99 + 13.36 + 2.77 = 17.1 \text{ pct}$$

$$\text{Raw coal sink ash, pct} = \frac{\text{pct raw coal sink in washed coal} \times \text{washed coal sink ash}}{\text{pct raw coal sink}} + \frac{\text{pct raw coal sink in refuse} \times \text{refuse sink ash}}{\text{pct raw coal sink}} + \frac{\text{pct raw coal sink in sludge} \times \text{sludge sink ash}}{\text{pct raw coal sink}}$$

$$= \frac{0.99 \times 27.9}{17.1} + \frac{13.36 \times 64.8}{17.1} + \frac{2.77 \times 53.8}{17.1}$$

$$= 1.62 + 50.63 + 8.75 = 61.0 \text{ pct}$$

$$\text{Qualitative efficiency, pct} = \frac{\text{pct washed coal float} - \text{pct raw coal float} \times 100}{100 - \text{pct raw coal float}}$$

$$= \frac{98.8 - 82.9 \times 100}{100 - 82.9} = 93.0 \text{ pct}$$

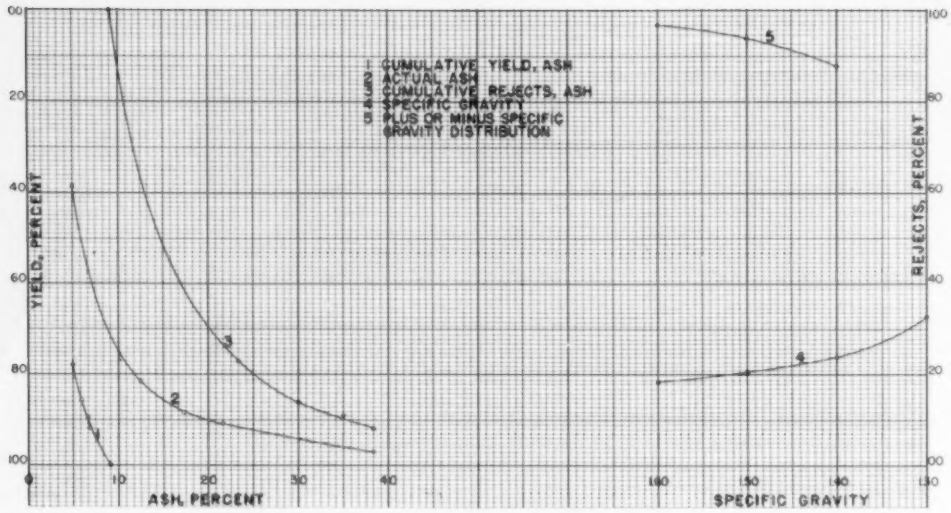


Fig. 3—Washability curves.

$$\text{Quantitative efficiency, pct} = \frac{\text{pct raw coal float} - \frac{\text{pct refuse float} \times \text{pct refuse}}{100}}{\text{pct raw coal float}} \times 100$$

$$= \frac{82.9 - \frac{1.8 \times 13.6}{100}}{82.9} \times 100 = 99.7 \text{ pct}$$

$$\text{General efficiency} = \frac{\text{qualitative efficiency} \times \text{quantitative efficiency}}{100}$$

$$= \frac{93.0 \times 99.7}{100} = 92.7 \text{ pct}$$

Drakeley's equations are used for calculating efficiencies. Even though other methods may be as accurate, it is felt that float-and-sink tests are a true criterion of washer efficiency since the separation is by specific gravity. Drakeley's formulas are based entirely upon specific gravity tests on refuse, washed coal, and raw coal. Some efficiency formulas depend upon both the ash content of the raw coal float and the refuse. Usually the refuse has a high ash content, from 50 to 70 pct, and contains large amounts of carbonates and iron compounds. It is difficult to duplicate determinations of ash accurately under these conditions, a fact recognized by the ASTM and consequently considerably more tolerance is allowed by the Society in the determination for ash in coals containing pyrite and carbonates. Quite often efficiencies calculated under these conditions are variable and sometimes are over 100 pct.

No efficiency formula has ever been derived that actually describes the efficiency of a plant completely, but any one of them can be of value if used continuously to study the operation of a given plant, in the routine adjustment of the plant from day to day, in the development and improvement of the plant, and in determining changes in the quality of the raw coal mined.

Data representing more than one day's results are reported weekly. Screen analyses and dustiness index tests are reported by the control laboratory, fig. 2.

Function of the Central Laboratory

The central laboratory is staffed with a chief chemist, chemist, technologist, and a technician. This laboratory performs the dual function of a central laboratory for all of the mines and a control laboratory for the mine at which it is located. On idle days, the technologist and technician aid in the general work of the central laboratory.

The central laboratory coordinates the efforts of all the control laboratories and performs other work such as:

1. Proximate analyses weekly of composite samples collected at the different mines by the control laboratories, see fig. 2. In addition, the raw coal mines collect samples of the coal produced for analysis periodically by the central laboratory.

2. Ultimate analyses for all of the mines periodically.

3. Analysis of ash periodically. This consists of a mineral break-down of the ash and includes, percentages of iron oxide, alumina, lime, silica, magnesia, alkalies, sulphate, and phosphorus pentoxide.

4. Investigation of coal quality in connection with acquisition of new coal lands. An investigation of a new coal property not only consists of the usual

washability study (fig. 3), but includes proximate analyses of the raw and theoretically washed coal, a description of the physical characteristics of the coal seam, see fig. 4, analysis of the seam by sections and described by drawings, ultimate analysis of the washed coal, grindability and swelling index of the washed coal, percentage of pyritic, organic, and sulphate sulphur in the washed coal, and a burning test of the washed coal. The latter includes apparent and true density of the clinker, ash-fusion temperatures of the clinker, and ignition temperature of the coal.

5. Supervision of drinking water and acid-water treatment and control at all of the mines.

6. Water analyses for control of boiler-feed water.

The central laboratory (fig. 5) is equipped and staffed to do other work such as: byproduct analyses, plasticity range, swelling and grindability indexes, some steel analyses, oil viscosity, research data of coal beneficiation processes, and investigation of individual units and circuits in any one plant to improve performance and reduce costs.

Table II. List of Equipment Used in the Central and Control Laboratories

Control Laboratory	
Coal moisture ovens, ASTM	Precision Scientific Co.
Electric muffle furnaces	Hoskins Mfg. Co.
Electric hot plate	Hoskins Mfg. Co.
Drying ovens	Fisher Scientific Co.
Analytical balance	Wm. Ainsworth & Sons
Air drying oven	Ayrshire Collieries Corp.
Raymond pulverizer	Robbins & Myers, Inc.
Dustability index apparatus	Ayrshire Collieries Corp.
Sturtevant sampling crusher	Sturtevant Mill Co.
Delatester	Reich Bros. Mfg. Co.
Hendrick test screen	Hendrick Mfg. Co.
Central Laboratory	
Water still	Barnstead Still & Sterilizing Co.
Fieldner electric furnace for volatile matter determination	Hoskins Mfg. Co.
Organic combustion furnace	Hoskins Mfg. Co.
Geiseler plastometer	Ayrshire Collieries Corp.
Fisher unitized gas analyzer	Fisher Scientific Co.
Laboratory chemicals	Eimer & Amend
Coal-ash melting point apparatus	Fisher Scientific Co.
Froth flotation apparatus	Denver Equipment Co.
Saybolt Universal Viscosimeter, ASTM	C. J. Tagliabue Mfg. Co.
Ro-Tap sieve shaker	W. S. Tyler Co.
Coal grindability apparatus	Janett Mfg. Co.
Friability test apparatus	Ayrshire Collieries Corp.
Laboratory furniture	Leonard Peterson & Co., Inc.

Conclusions

A laboratory system can be of value only if it is well organized and if the operating and sales companies make full use of the information it supplies. A well-organized laboratory system more than pays for itself in many ways because it reduces operating costs and provides the seller with all the information he needs about his product in placing the coal for efficient, economic, and satisfactory service. Advertising to the consumer alone has a value that cannot be measured in dollars and cents but nevertheless is valuable because it increases the will of the customer to buy from an organization that can maintain and assure him of a uniform product.

No doubt much more useful information could be developed in a laboratory system than is done by the Ayrshire organization, but it is felt that economic considerations should limit the laboratory activities to a point at which they are not only useful, but practical as well.

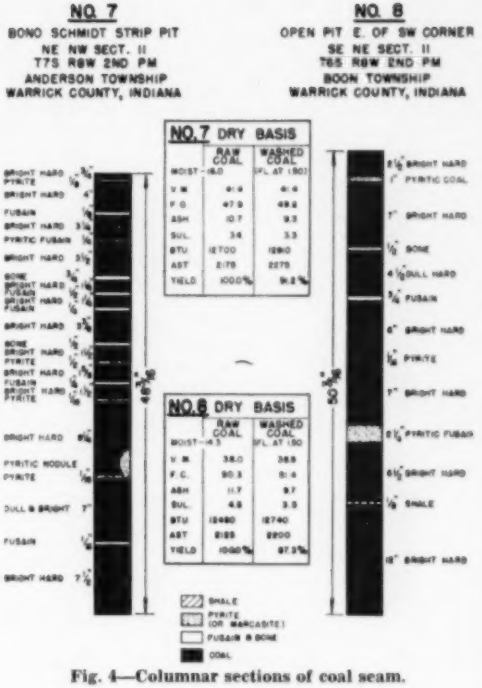


Fig. 4—Columnar sections of coal seam.

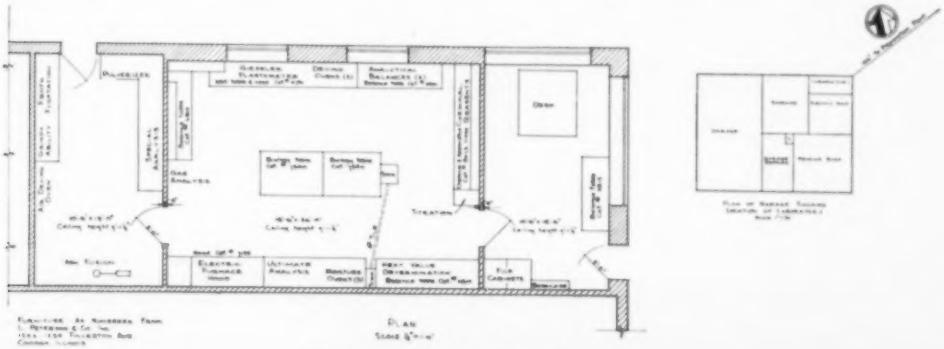


Fig. 5—Laboratory at Harmattan mine.

The Mechanism of Coarse Coal and Mineral Froth Flotations

by

Shiou-Chuan Sun

and

R. E. Zimmerman

An evaluation of the mechanism surrounding the froth flotation of coarse coal and mineral particles as a result of experiments conducted at The Pennsylvania State College. Maximum size ranges for both bituminous and anthracite coals were established as well as the factors affecting the floating of coarse particles.

CONSIDERABLE interest is developing in the froth flotation of coal and the maximum particle sizes which can be treated by such method. The economic necessity of recovering extreme coal fines and slurries plus the restrictions being placed upon stream pollution have brought about many new and prospective installations of flotation plants.

Most coal slurries or silts have a wide size range, some sizes of which may be unsuitable for effective froth flotation. This fact also enters into the froth flotation of other minerals and the principles that apply to coal would also apply to minerals in general.

SHIOU-CHUAN SUN and R. E. ZIMMERMAN, Members AIME, are Assistant Professor and Division Chief, respectively, Division of Mineral Preparation, The Pennsylvania State College, State College, Pa.

Joint AIME-ASME Fuels Conference, French Lick, October 1949.

TP 2843 F. Discussion (2 copies) may be sent to Transactions *AIME before June 30, 1950. Manuscript received Sept. 12, 1949.*

A series of experiments were made by the authors for the purpose of investigating factors influencing the froth flotation of coarse mineral particles and an attempt has been made to evaluate those factors.

This paper presents the results of a study of the froth flotation of coal particles in the size range greater than 35 mesh. During the study a "multi-bubble" hypothesis has been developed to explain the various phenomena observed in the behavior of coarse particles in froth flotation of coal.

The terms coarse, intermediate, and fine particles as used in this paper are arbitrary and differ for various minerals. For coal alone the term intermediate particles means that the particle size is within the range of 35 and 200 mesh of Tyler sieve sizes. Sizes of coal particles coarser and finer than this size range are termed respectively as coarse and fine particles.

Methods of Conducting Flotation Experiments: All of the flotation tests, except those shown in table I, were carried out in a laboratory Fagergren flotation machine, using 300-g samples of solids for each test. All mineral samples were prepared from selected lumps of high purity by crushing, grinding, and screening to the desired sizes. Except coals, all the other samples were cleaned through magnetic

separation, tabling, washing with dilute hydrochloric acid and distilled water, and finally dried and stored in large glass jars. Before each test the dry sample was soaked 30 min in water. Tap water was used for all flotation tests. The pH values were regulated with sodium hydroxide and hydrochloric acid and measured by means of a Beckman pH meter. The rate of aeration was regulated and measured by connecting the petcock of flotation cell

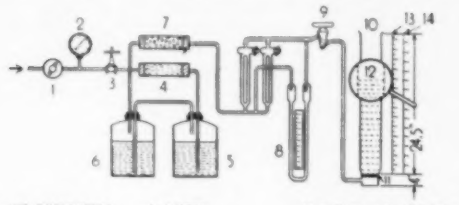


Fig. 1—Schematic diagram of a froth meter.

to one of the three different scaled rotameters which was in turn connected to the regulating system of compressed air. The rotameters were standardized by means of a water displacement method[3] and connected to a manometer. The magnitude of agitation in the flotation cell was indicated by the speed of impeller, which in turn was adjusted with a motor of varying speed and measured by a revolution counter.

The tests of table I were carried out in a small Denver agitation flotation machine with a capacity of 35 g of solid feed. The froth was removed at four time intervals of 0 to 0.5, 0.5 to 1, 1 to 2, and 2 to 3 min and collected respectively into four beakers which had been standardized. The volume of the collected material was measured immediately after removal and again after the froth had disappeared. The difference in these two measurements was the volume of froth (col. 2). The collected water and coal were separated by filtration and the filtrate was measured in a graduate. Of the collected water, 90 pct was assumed as being removed mechanically from the pulp and the other 10 pct as froth water. The coal particles were dried and weighed. The number of coal particles (col. 4) were counted with the aid of a microscope. The average weight of a single coal particle (col. 5) in the samples of 3x6 mesh was determined by weighing, and that finer than this size was calculated. In the calculation of col. 8, the surface area of a single coal particle was averaged from that of its corresponding sphere and cube.

Methods of Conducting Visual Observations with a Frothmeter: The behavior of particles and bubbles in a flotation cell is difficult to observe because of the complexity of the system. For this reason, a frothmeter, as shown in fig. 1, was constructed and used to observe the conditions existing in an operating cell. The glass cylinder of the frothmeter, illuminated longitudinally from the back and two sides with three fluorescent light tubes, has an inside diameter of 2.2 in. and can be aerated at any rate between zero and 500 cc air flow per second.

The data of table II were established by filling the glass cylinder with 1000 cc of distilled water

Table I. A Proximate Estimation of the Number of Air Bubbles Required for the Flotation of Various Sizes of Bituminous Coal Particles Taken from the Midland Mine of Houston, Pa., in an Agitation-type Flotation Cell with 0.45 Lb per Ton Pine Oil at Constant pH 7.0 ± 0.2

Test No.	Particle Size (Mesh)	Time Period of Froth Removal (Min)	Measured Vol. of Removed Froth (Cc.)	No. of 2 Mm Diam Air Bubbles in the Removed Froth (Calculated)	No. of Particles in the Removed Froth (Counted)	Averaged Wt of One Particle (Mg)	No. of Particles Floated by One Air Bubble (Calc.)	No. of Air Bubbles Used for Floating One Particle (Calc.)	Max. No. of Air Bubbles Theoretically Packed on One Particle (Calc.)	Recovery Pct
		1	2	3	4	5	6	7	8	9
1	3x6	0-0.5	7.75	1,930	20	35.6	0.0104	96.0	47.7	2.04
2	3x6	0.5-1	12.411	3,090	5	57.0	0.0016	618.0		0.18
3	3x6	1-2	12.0	2,990	3	166.0	0.0010	985.0		1.42
4	3x6	2-3	20.0	4,980	3	166.5	0.0006	1,600.0		1.43
5	6x8	0-0.5	20.96	5,220	934	7.85	0.1785	5.6	12.6	20.90
6	6x8	0.5-1	15.94	3,980	151	9.25	0.0380	26.3		3.09
7	6x8	1-2	21.33	5,300	102	9.95	0.0192	52.0		2.89
8	6x8	2-3	35.78	8,900	29	10.1	0.0033	307.0		0.84
9	8x10	0-0.5	26.65	6,630	1,955	5.82	0.2940	3.4	6.0	31.91
10	8x10	0.5-1	29.96	7,450	1,550	5.96	0.2085	4.8		26.50
11	8x10	1-2	13.38	3,330	502	6.12	0.1515	6.6		8.75
12	8x10	2-3	23.39	5,820	296	6.35	0.0513	19.5		5.41
13	10x14	0-0.5	31.4	7,820	6,640	2.3	0.834	1.2	2.98	41.90
14	10x14	0.5-1	33.58	8,350	3,545	2.4	0.435	2.3		24.72
15	10x14	1-2	28.39	7,060	960	2.8	0.137	7.3		7.94
16	10x14	2-3	28.01	6,980	369	2.5	0.028	18.92		2.60
17	14x28	0-0.5	51.2	12,790	52,600	0.5	4.1	0.24	1.99	75.10
18	14x28	0.5-1	36.74	9,150	4,953	0.5	0.54	1.85		8.55
19	14x28	1-2	66.01	16,420	1,269	0.7	0.077	12.95		3.37
20	14x28	2-3	60.57	15,080	214	0.7	0.014	70.40		0.43
21	28x35	0-0.5	47.31	11,800	338,000	0.11	28.6	0.035	0.38	87.90
22	28x35	0.5-1	58.42	14,520	21,100	0.13	1.5	0.667		7.84
23	28x35	1-2	71.85	17,900	3,550	0.13	0.2	5.01		1.32
24	28x35	2-3	50.95	12,690	1,790	0.14	0.14	7.08		0.93
25	35x48	0-0.5	55.90	13,900	967,000	0.033	69.5	0.0144	0.19	91.20
26	35x48	0.5-1	34.59	8,600	44,700	0.036	5.2	0.1923		4.57
27	35x48	1-2	60.55	15,100	15,600	0.038	1.0	1.0		1.69
28	35x48	2-3	46.74	11,620	1,975	0.039	0.17	5.89		0.22
29	48x65	0-0.5	69.00	17,200	2,630,000	0.012	147.0	0.0068	0.095	97.5
30	48x65	0.5-1	47.77	12,380	214,000	0.013	17.6	0.0568		7.74
31	48x65	1-2	68.24	17,000	71,400	0.014	4.19	0.2390		2.87
32	48x65	2-3	59.15	14,720	47,400	0.014	3.22	0.3106		1.84
33	150x200	0-0.5	209.85	52,200	65,500,000	0.0005	1,260.0	0.0009	0.012	93.50
34	150x200	0.5-1	102.2	25,500	2,321,000	0.0006	91.2	0.0110		3.97
35	150x200	1-2	94.64	23,600	572,000	0.0006	23.21	0.0431		0.98
36	150x200	2-3	71.40	17,800	151,300	0.0007	8.51	0.1177		0.30

Table II. Visual Observation of the Number of Air Bubbles Attached to Different Sizes of Coarse Mineral Particles in a Frothmeter Containing 1000 cc of Chemical Solution and Having a Constant Rate of Aeration of 300 cc Per Square Inch Per Min

Minerals	Size of Particle (Tyler Mesh)	Wt of Particle (Mg)	Behavior of Particle (Observed)	Time of Particle Falling in Solution Before Starting to Float, Sec	No. of Attached Air Bubbles (Observed)	Calculated Load Carried by Each Attached Air Bubble (Mg)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bitu. Coal[a]	+3	578.1	Sink		70-80[b]	7.2-8.3[b]
Bitu. Coal	+3	286.3	Float[c]	97	40-50	5.7-7.2
Bitu. Coal	3x6	96.2	Float[c]	32	15-20	4.9-6.5
Bitu. Coal	3x6	47.0	Float	8	6-11	4.7-5.9
Bitu. Coal	6x8	9.1	Float	3	2-3	3.0-4.5
Bitu. Coal	8x10	6.3	Float	2	1-2	3.1-6.3
Bitu. Coal	10x14	2.5	Float	1	1	2.5
Bitu. Coal	14x20	0.7	Float	0.5	1	0.7
Quartz[d]	6x8	31.6	Sink		4-5[b]	6.3-7.9[b]
Quartz	8x10	17.2	Float[c]	31	3-4	4.3-5.7
Quartz	10x14	7.5	Float[c]	7	1-2	3.6-7.3
Quartz	14x20	1.8	Float	1	1	1.8
Galena[e]	8x10	27.5	Sink		3-4[b]	6.9-9.2[b]
Galena	14x20	5.7	Float[c]	3	1	5.7

[a] Bituminous coal taken from East diamond mine, West Kentucky, tested in a solution of 105 mg per liter light oil and 125 mg per liter pine oil at constant pH 7.5 ± 0.2.
[b] The number of bubbles attached to sink particles were observed two minutes after their settling on the bottom of the glass cylinder.
[c] Only a few of the many added particles were floated with difficulty.
[d] Pure quartz particles tested in a solution of 22 mg per liter L-Am-Hcl and 40 mg per liter pine oil at constant pH 10.6 ± 0.2.
[e] Pure galena particles tested in a solution 165 mg per liter iso-amyl-X and 125 mg per liter pine oil at constant pH 7.5 ± 0.2.

and flotation reagents. This solution was aerated with a constant rate of air flow of 300 cc per sq in. per min. The screen-sized mineral particles were soaked 30 min in distilled water, then conditioned 5 min in the same solution as that used in the glass cylinder, and finally introduced slowly a few at a time into the solution of the glass cylinder by means of a glass funnel. The behavior of the mineral particles (cols. 4, 5, 6) was determined with the aid of a magnifying glass and a stop watch. The floated and sunk particles were collected, dried, and weighed (col. 3).

A similar procedure was used for obtaining the data of table III, with the following exceptions: (1) the rate of aeration was varied for different tests; and (2) the sample used for each test was 7 g in weight and consisted of all sizes of coal particles.

Rising of Coarse Particles Requires Attached Multi-Bubbles: The results of the experiments described are tabulated in tables I and II. Although some of the data had to be approximated, they are sufficiently close to show certain important factors which affect the floating of coarse particles.

They show that for successful flotation operation, the number of particles capable of being carried by a single air bubble is decreased with the increase of particle size. When the size of a particle becomes too coarse, then the downward force exerted by the particle will be larger than the buoyant force of a single bubble. The result is that this coarse particle has to be floated with more than one attached bubble. The upper floatable size limit is reached when the particle becomes so coarse that it can be floated only by having its entire surface filled with a loosely

Table III. The Behavior of Anthracite Coal Particles and Bubbles in a Frothmeter Containing 1000 cc of Distilled Water, 165 mg of Petroleum Light Oil and 125 mg of Pine Oil, at Constant pH 7.5 ± 0.2

Test No.	Rate of Aeration, Cc per in² per Min	Calculated Layers of Closely Packed 2.0 Mm Air Bubbles Layer per Sec	Wt of Largest Anthracite Coal Particle Floated, Mg.	Results of Visual Observation	
				Pulp Turbulence	Behavior of Particles and Bubbles
	(1)	(2)	(3)	(4)	(5)
1	50	0.97	3	None	Bubbles were few and widely spaced from one another. Pulp volume increased very little. Few intermediate but not coarse particles attached to bubbles. No collision.
2	100	1.94	4	Weak	
3	150	2.91	5	Weak	
4	200	3.89	13	Weak	
5	250	4.86	37	Moderate	Bubbles were moderately abundant and less widely spaced. Pulp volume slightly increased. Many intermediate but only few coarse particles attached to bubbles. Few collisions.
6	300	5.82	44	Moderate	
7	350	6.79	79	Moderate	
8	400	7.76	157	Strong	Bubbles were plentiful and closely spaced. Pulp volume moderately increased. Intermediate and coarse particles attached to bubbles. Floating particles collided gently with the wall of glass cylinder.
9	450	8.73	242	Strong	
10	500	9.70	231	Strong	
11	550	10.67	214	Strong	
12	600	11.60	115	Strong	
13	650	12.63	47	Violent[a]	Particles were drawn into many local vortexes to collide with one another and with the wall of glass cylinder by eddying current. Pulp volume greatly increased.
14	700	13.59	22	Violent[a]	
15	800	15.52	11	Violent[a]	
16	900	17.46	8	Violent[a]	

[a] Violent turbulence is characterized by the presence of many local vortexes and eddying currents in the pulp.

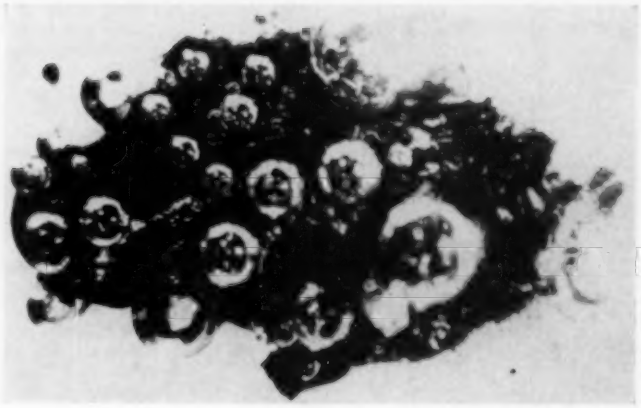


Fig. 2 — Micrograph shows the attachment of multi-bubbles on the surface of a large but very thin bituminous coal particle floated with 0.8 lb per ton petroleum light oil and 0.5 lb per ton pine oil at pH 7.3. Magnification 10X.

packed monolayer of individual bubbles as shown in fig. 2.

Mathematically, the motion of a mineral particle attached to bubble or bubbles in a homogeneous and quiescent pulp can be expressed on the basis of Newton's law of motion as:

$$F_b - F_p - F_r = ma \qquad [1]$$

in which F_b, F_p, and F_r are, respectively, the force of buoyancy, gravity, and resistance; m is the total mass of the particles and its attached air bubbles; a is the upward acceleration; and all are in CGS units. Eq 1 can be written in detail as:

$$(V_m + \Sigma V_b)D_p g - (V_m d_m + \Sigma V_b d_b)g - F_r = (V_m d_m + \Sigma V_b d_b)a \qquad [1a]$$

in which V_m, V_b, and ΣV_b are, respectively, the volume of one mineral particle, one attached bubble, and all bubbles attached to one mineral particle. Symbols d_m, d_p, and d_b are, respectively, the mass density of mineral, pulp, and bubble.

It can be seen from Eq 1 that the particle is ascending when $F_b - (F_p + F_r) > 0$, or $F_b > (F_p + F_r)$. When the particle is not moving, or under equilibrium condition, then a and F_r are both equal to zero, and Eq 1a reduces to Eq 1b.

$$\Sigma V_b (d_p - d_b) = V_m (d_m - d_p) \qquad [1b]$$

Practically, d_b is very small and may be neglected, then

$$\Sigma V_b d_p = V_m (d_m - d_p) \qquad [2]$$

$$\Sigma V_b = V_m \left[\frac{d_m}{d_p} - 1 \right] \qquad [2a]$$

$$\frac{\Sigma V_b}{V_m} = \frac{d_m}{d_p} - 1 \qquad [2b]$$

From the above equations it can be concluded that:

1. With a constant ratio of mineral density to pulp density, the volume or number of attached bubbles required for floating a single particle is directly proportional to the size of the particle.

2. With particle size and pulp density being kept constant, the volume or number of attached bubbles required for floating a single mineral particle is directly proportional to the density of the particle.

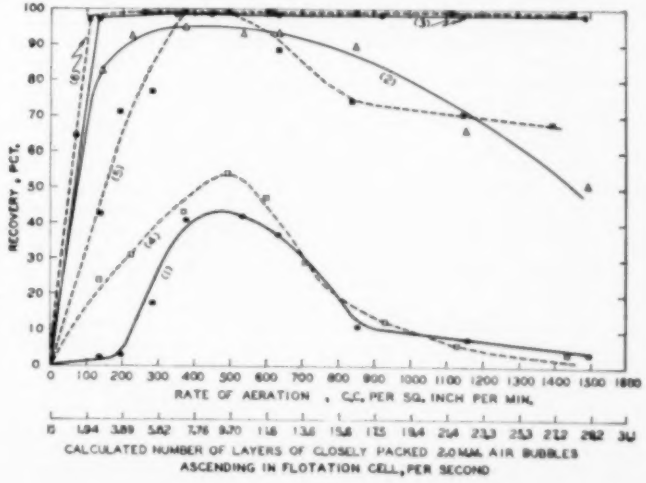

RECOVERY, PCT.
RATE OF AERATION, C.C. PER SQ. INCH PER MIN.
CALCULATED NUMBER OF LAYERS OF CLOSELY PACKED 2.0 MM. AIR BUBBLES ASCENDING IN FLOTATION CELL, PER SECOND

Fig. 3—Effect of aeration on the flotation of minerals.

Flotation time, 3 min; pulp dilution, 7.7; impeller speed 1623 rpm; pH, 7.5 ± 0.2.

Curves 1, 2, and 3 indicate respectively 8x10, 14x20 and 48x65 mesh Pittsburgh bituminous coal floated with 0.66 lb per ton petroleum light oil and 0.4 lb per ton pine oil.

Curves 4, 5, and 6 indicate respectively 35x48, 65x100, and —200-mesh galena floated with 0.2 lb per ton iso-amyl-X and 0.36 lb per ton pine oil.

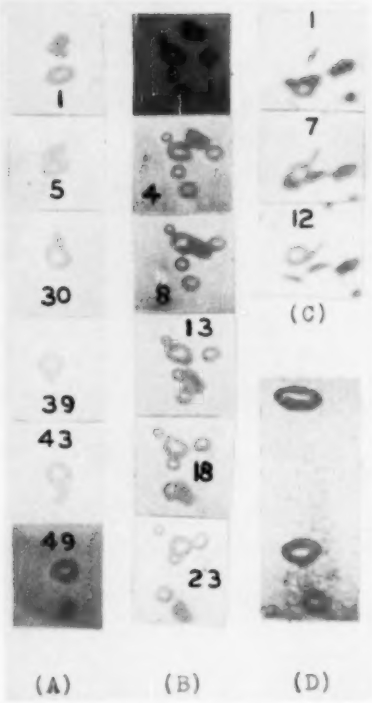


Fig. 4—High speed motion photographic pictures show the difficulty of establishing permanent attachment between coarse particle and air bubble.

3. With other factors being kept constant, the buoyant force of the particle attached to bubbles is directly proportional to pulp density.

Multi-Bubble Hypothesis: The satisfactory correlation of the experimental data, as presented in this paper, has been obtained by assuming that the phenomena of the flotation of coarse mineral particles can be explained by means of a proposed "multi-bubble" hypothesis. The essential ideas of this hypothesis can be grouped into three parts: (1) the rising of an extremely coarse particle at a sufficient speed[3] for successful flotation requires the attachment of more than one air bubble to the particle surface; (2) the attachment of many air bubbles to a coarse particle of sufficient contact angle requires a suitable rate of aeration to provide a thick net of several layers of closely spaced air bubbles in the traveling path of the particle, and an amount of agitation sufficient to keep the particle in suspension; and (3) violent pulp turbulence, usually resulting from either excessive rate of aeration or extremely high amount of agitation or both, is detrimental to the existence of multi-bubbles on a coarse particle.

The hypothesis is not entirely new. Gaudin[1] has calculated the necessary ratio of bubble size to particle size for successful flotation, and reported the upper size limit of floatable particles. Plante and Sutherland[4] have observed the attachment of more than one air bubble to a single rye grain, and derived equations to express the buoyant force of the many attached bubbles. Furthermore, many flotation investigators in the past may have noted the attachment of many bubbles to a single coarse mineral particle. On the other hand, it is also a fact that this previous work covered more or less only the idea of part 1 but not that of parts 2 and 3 of the present multi-bubble hypothesis. The last two parts of the hypothesis, dealing chiefly with the influence of aeration, agitation, and pulp turbulence on the flotation of coarse particles, the authors believe to be new.

Effect of Aeration on Particle-bubble attachment: By means of a frothmeter, the events of particle-bubble attachment and pulp turbulence under various rates of aeration were observed, as shown in table III. The method of conducting these observations has been previously described. Table III shows that the attachment of intermediate particles to bubbles can take place in the presence of almost any number of air bubbles and can survive the crisis of violent pulp turbulence. On the other hand, a permanent attachment of an extremely coarse particle to multi-bubbles requires the presence of not a few bubbles but a thick net of several layers of closely spaced bubbles in the traveling path of the particle. The optimum rate of aeration for the attachment of coarse particle to multi-bubbles is limited to a range of 400 to 600 cc air per sq in. per min, which is equivalent to respectively 7.76 and 11.6 ascending layers of closely packed 2.0 mm bubbles per sec. These are in agreement with the results of actual flotation tests, as shown in fig. 3.

The reasons for the lack of permanent attachment of coarse particle to multi-bubbles in the presence of insufficient number of air bubbles were disclosed by means of high speed motion photographs, as shown in fig. 4. These motion photographs were obtained by means of a technique similar to that described by Spedden and Hannan, Jr.,[5] with the exceptions of: (1) having no microscope, (2) using an Eastman D-II high speed camera operating at approximately 1080 frames per second. Referring to fig. 4, the sequence of action photographed proceeds from top to bottom with number of frames shown. Parts *A* and *B* on fig. 4 show that the momentum of motion of an 8x10 mesh galena particle in a solution of 20 mg potassium ethyl xanthate per liter of water is probably larger than the bound force of one or two attached bubbles, so the attachment was torn apart in a split second. Part *C* indicates that the attachment of two 10x14 mesh coal particles to one air bubble in a solution of 25 mg petroleum light oil per liter of water is incompatible and easily broken by collison with a third particle in the pulp. Part *D* shows that particle-bubble attachment is increased by reducing the size of galena particles to 100x150 mesh, as indicated by the increase of thickness and size of the air bubble passing through a stream of falling particles in a solution same as that of parts *A* and *B*.

Pulp Turbulence: The low floatability of coarse particles but not of intermediate particles at excessive aerations and/or agitation, as shown in figs. 3 and 5, is caused chiefly by the presence of violent turbulence and to a much less extent by the lowering of pulp density. It was observed by means of the frothmeter that coarse particles attached to many bubbles are clumsy and more subject to collision

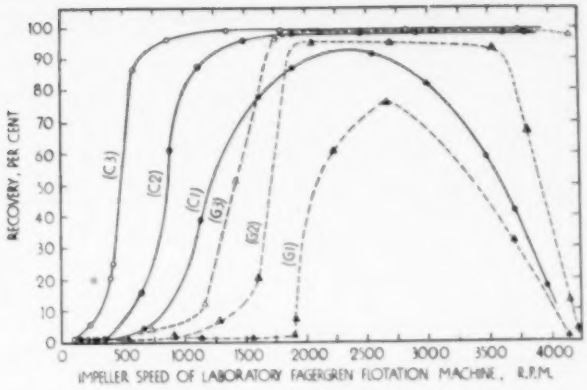


Fig. 5 — Effect of agitation on the flotation of minerals in a laboratory Fagergren machine with constant aeration of 440 cc per sq in. per min and a constant flotation period of 3 min.

Curves G1, G2, and G3 indicate respectively 28x35, 48x65, and 100x200-mesh galena floated with 0.2 lb per ton iso-amyl-X, 0.36 lb per ton pine oil, at constant pH 7.5 ± 0.2. Curves C1, C2, and C3 indicate respectively 10x14, 35x48, 100x200-mesh Pittsburgh bituminous coal floated with 0.66 lb per ton petroleum light oil, 0.4 lb per ton pine oil, at constant pH 7.5 ± 0.2.

with other materials in the pulp. The frequency of collision is increased with the increase of pulp turbulence, as shown in col. 5 of table III. In a violently turbulent pulp, the surface of a coarse particle is subjected to constant rubbing by the tearing force of eddying currents and the disruptive force of other materials. The result is that the particle-bubble attachment is difficult to maintain under this circumstance.

On the other hand, bubbles mineralized with intermediate and small particles were observed to have smooth surface (see part *D* of fig. 4), higher mobility, firm particle-bubble attachment and elastic bubble wall. The high speed movie, similar to fig. 4 but not shown here, indicates that the collision of this kind of bubbles in solution is similar to the striking of two tennis balls in air. The collided bubbles are usually bounced away and occasionally coalesced into one larger bubble, but seldom broken. Consequently, the floatability of intermediate and small particles is less affected by pulp turbulence.

In regard to the small influence exerted by the lowering of pulp density, col. 5 of table III indicates that at excessive rate of aeration the volume of air bubbles entrapped in the pulp is greatly increased, as indicated by the increase of pulp volume, and the pulp density is lowered. To a lesser extent, pulp density should also be lowered at excessive agitation, as caused by the sucking of more air into the flotation pulp. According to the equations given above, the lowering of pulp density reduces the buoyant force. This may have an ill effect on the floatability of coarse particles but not of small particles.

Agitation and Mineral Density: With respect to the effect of agitation on the flotation of coarse particles, fig. 5 shows that the minimum magnitude of agitation required for a successful flotation operation is increased with the increase of particle size and mineral density. This can be explained by the observed fact that the suspension of mineral particles in liquid is a prerequisite of particle-bubble attachment. The amount of agitation used for keeping the coarse and heavier particles in suspension has to be larger than that of the smaller and lighter particles. The declining of floatability of coarse particles at an extraordinarily large amount of agitation is caused by the increase of pulp turbulence, as discussed previously.

With respect to mineral density, fig. 6 shows that the upper floatable size limit of mineral particles under the most optimum flotation conditions is decreased with the increase of mineral density. This

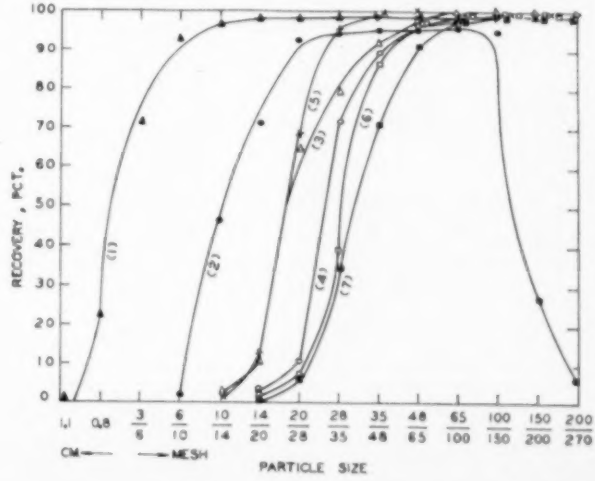


Fig. 6 — Maximum particle size of different minerals floated under the most optimum conditions of flotation in a laboratory Fagergren machine with constant aeration of 426 cc per sq in. per min and constant impeller speed of 2193 rpm.

Curve 1: Bituminous coal (1.35) taken from Midland mine, Houston, Pa., and floated with 1.2 lb per ton petroleum light oil, 0.8 lb per ton pine oil, at constant pH 7.0 ± 0.2.
Curve 2: Philadelphia and Reading anthracite coal (1.54) with 2.04 lb per ton Squibb mineral oil, 0.864 lb per ton pine oil at constant pH 7.2.
Curve 3: Quartz (2.65) with 0.32 lb per ton L-am-Hcl, 0.6 lb per ton pine oil at constant pH 10.6 ± 0.2.
Curve 4: Fluorite (3.1) with 0.27 lb per ton $CuSO_4.5H_2O$, 0.52 lb per ton Na-oleate, 0.6 lb per ton pine oil, at constant pH 8.8.
Curve 5: Sphalerite (4.0) with 0.11 lb per ton $CuSO_4.5H_2O$, 0.33 lb per ton iso-am-X, 0.6 lb per ton pine oil, at constant pH 6.5.
Curve 6: Pyrite (5.0) with same reagents as curve 5 at constant pH 4.5.
Curve 7: Galena (7.5) with same reagents as curve 5 at constant pH 7.5.

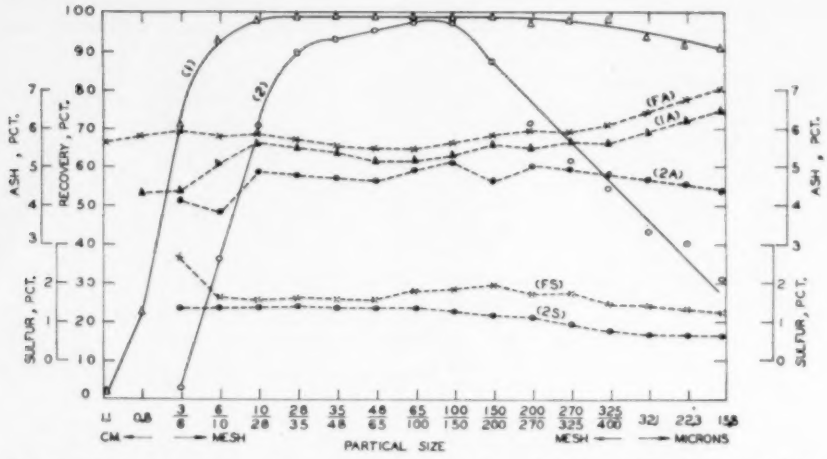


Fig. 7—Effect of flotation reagents on upper floatable particle size of bituminous coal taken from Midland mine, Houston, Pa., and floated at constant pulp dilution 7.7 and pH 7.2 ± 0.2.

Curve 1: Floated with 1.2 lb per ton petroleum light oil and 0.8 lb per ton pine oil. Curve 2: Floated with 0.4 lb per ton pine oil. Curves FA, 1A, and 2A: Ash per cent of feed, concentrate 1, and concentrate 2, respectively. Curves FS and 2S: Sulphur per cent of feed and concentrate 2, respectively.

apparently is caused by the fact that when two particles have the same weight the one with higher density must have a smaller specific surface area[1] than the other with a lower density. The number of air bubbles that can be attached to coarse particles is directly proportional to the specific surface area of the particle. From fig. 6, it can be seen that the maximum size of bituminous and anthracite coal particles which can be floated practically is respectively 3x6 and 14x20 mesh.

Flotation Reagents and Deep Scraping: In regard to flotation reagents, fig. 7 shows that within a certain limit the coarseness of the floatable particles is increased with the increase of amount or grade of the flotation reagents used. This is caused by the improvement of both the contact angle of particles and the number and quality of air bubbles. The result is that the attachment of multi-bubbles to coarse particles increases.

The floated coarse particles were observed to be held in most cases in the interface between the pulp surface and the froth instead of in the body of the froth. This is probably due to the coarseness of the particles and the low density of the froth body. Consequently deep scraping of the froth is needed to remove the floated coarse particles from a flotation cell.

Summary

1. The maximum size of bituminous and anthracite coal particles which can be efficiently floated in a laboratory Fagergren flotation machine is found to be respectively 3x6 and 14x20 mesh.

2. The factors influencing the froth flotation of coarse mineral particles are aeration, agitation, pulp turbulence, flotation reagents, and mineral density. The phenomena of flotation of coarse particles can be interpreted by means of a proposed multi-bubble hypothesis.

3. The optimum rate of aeration for the flotation of coarse particles in a laboratory Fagergren flotation machine is in the vicinity 450 cc air per sq in. per min.

4. The minimum amount of agitation required for the flotation of coarse particles must be large enough to keep the particles in suspension, and is increased with the increase of mineral density and particle size.

5. Violent pulp turbulence, usually resulting from excessive aeration or agitation or both, is detrimental to the successful flotation of coarse particles.

6. Other factors being constant, the coarseness of floatable particles, to a certain limit, can be increased with the improvement of flotation reagents.

7. The upper floatable size limit of mineral particles under the most optimum conditions of flotation is reduced with the increase of mineral density.

8. Deep scraping is needed to remove the floated coarse particles from a flotation cell.

Acknowledgment

The writers wish to express their appreciation to Professor D. R. Mitchell for his heartening encouragement and helpful criticism. Thanks are due Mr. Charles W. Young and Mrs. Barbara Weigand for their cooperation in the work of high speed motion photography. Also appreciation is expressed to Dr. T. C. Tsu for his kind assistance in deriving the equations and to Messrs. H. T. Darby, C. D. Neubling, and H. Lovell for their work in chemical analysis.

References

[1] A. W. Fahrenwald: The Aerating Capacity of Flotation Machines. Pamphlet 64. Univ. of Idaho (July, 1943).

[2] A. W. Fahrenwald: Size of Mineral Particles in Relation to Flotation Concentration. Pamphlet 2. Univ. of Idaho (1931).

[3] A. M. Gaudin: Flotation. Pp. 106, 152. (1932) New York. McGraw-Hill Book Co.

[4] E. C. Plante and K. L. Sutherland: The Physical Chemistry of Flotation X. The Separation of Ergot from Rye. *Jnl. Phys. Chem.* (1944) **48**, 203.

[5] H. P. Spedden and W. S. Hannan, Jr.: Attachment of Mineral Particles to Air Bubbles in Flotation. *Trans.* AIME (1949) **183**, 208; *Min. Tech.* (March 1948) TP 2354.

AIME OFFICERS
Donald H. McLaughlin, *President*
Vice Presidents
R. W. Thomas A. B. Kinzel
C. H. Benedict Philip Kraft
Andrew Fletcher, *Vice-President and Treasurer*
AIME STAFF
E. H. Robie, *Secretary* E. J. Kennedy, Jr., *Asst. Secy.*
H. A. Maloney, *Asst. Treas.*
Ernest Kirkendall, *Asst. Secy.* H. N. Appleton, *Asst. to Secy.*

aime NEWS

1951 Officers Announced, Also Committeemen, Bylaw Change, Publications, at Mar. 15 Meeting

Announcement was made at the meeting of the Executive and Finance Committees of the AIME, at their meeting at the Engineers' Club, New York, on March 15, of the official ticket for Institute officers for 1951. W. M. Peirce heads the ticket, as the nominee for President. Mr. Peirce is chief of the research division of The New Jersey Zinc Co., at Palmerton, Pa. He is a member of the Institute of Metals Division of the Institute and has long been active in its executive councils. He served as a Director from 1937 to 1940, and thereafter was Vice-President for three years. Last year he again began serving a three-year term as Director, and is currently a member of the Executive Committee.

For Vice-Presidents, Joseph L. Gillson and Michael L. Haider were nominated, representing the Mining and Petroleum Branches respectively. Directors named were: Thomas G. Moore, Charles E. Lawall, John F. Myers, Fay W. Libbey, and A. C. Rubel. The Nominating Committee, O. B. J. Fraser chairman, met during the Annual Meeting. No letter ballot will be necessary unless 25 or more members offer a different complete or partial ticket before Sept. 1. Brief biographical sketches of each official nominee will be published in the July issues of the journals.

The Committees considered the request of the Council of the new Mining Branch of the Institute that part-time Eastern and Western paid secretaries be named to handle its affairs. No action was taken on the Western secretary, but approval was given of the diversion of half of John V. Beall's time, as editor of Mining Engineering, to secretarial duties for the Mining Branch. To assist him on the monthly journal a technically trained assistant editor was authorized. This man, when secured, will also assist in the editing of the Journal of Metals, of which Thomas E. Lloyd has succeeded Thomas W. Lippert as editor.

Provided the Admissions Committee approves, the Executive and Finance Committees looked with favor on a recommendation from the Council of Section Delegates that special consideration should be given to Junior Members transferring to a higher grade of membership. Upon reaching the age of 33 they are, according to the present bylaws, obliged to pay a $20 initiation fee and $20 annual dues as Associate Member or Member. The Section Delegates recommended that $1 per year of continuous dues-paying membership as a Student Associate or Junior Member be credited on the initiation fee, up to a maximum of $10. A change in the bylaws to effect this will be voted upon by the Board at its meeting on June 22.

In addition to the awards already authorized for presentation at the Annual Meeting in 1951, the Committees authorized the third award of the Erkine Ramsey Medal. This was made possible by a gift of $500 from Paul Weir, 1950 medalist, as an addition to the income of the Medal Fund.

Ross J. Leisk was named as chairman of the auxiliary publications committee of the Mining Subdivision; Richard H. Hunt, of the Geology Subdivision; and H. LeRoy Scharon, of the Geophysics Subdivision. The duties of these committees will be to review technical papers offered for Institute publication in their respective fields and make recommendations to the AIME Technical Publications Committee as to acceptance. As to the last-named committee, Francis B. Foley was appointed chairman to succeed E. C. Meagher, resigned. Lloyd C. Gibson was appointed to the Admissions Committee, succeeding T. B. Counselman, resigned.

Microfilming of current volumes of the three AIME journals by University Microfilms, Ann Arbor, Mich., was approved. This concern will offer these microfilms for sale to those who wish to preserve Institute publications in this way instead of the more bulky volumes as printed. C. H. Mathewson was authorized to begin preparation of a revised edition of "Modern Uses of Nonferrous Metals", a Seeley W. Mudd Memorial Fund volume. E. R. Kaiser was reappointed to serve as AIME representative on the Engineering Foundation board for a term of four years. The scheduled Board meeting for Wednesday, June 21, was postponed until the afternoon of Thursday, June 22, to be followed by a Directors' dinner at the Engineers' Club at which the Rand Medal for 1950 will be presented to Francis H. Brownell.

A memorandum from the Institute staff suggesting a more economical method of handling AIME publications was approved. Heretofore members

have been allowed a special price on most Institute publications provided they purchase only one copy; if more than one they must pay the nonmember price. This required detailed records of members' purchases, checking of all members' orders, and often considerable correspondence. The suggested plan is to rescale the nonmember prices of all Institute publications except the journals, and to allow members and libraries a 30% discount from these prices, and dealers a 20% discount, with no limit as to the number purchased. The new price list will be offered for Board approval at the April 21 meeting. On Transactions volumes a 50% discount will be allowed if members order the volume when paying their dues.

Earle E. Schumacher, vice-chairman, presided at the meeting, with E. C. Meagher and W. M. Peirce, of the Executive Committee, present, and Erle V. Daveler, A. B. Kinzel, and Gail F. Moulton, of the Finance Committee, and Andrew Fletcher, Treasurer, and Edward H. Robie, Secretary.

Proposed Amendment to Bylaws

Notice is hereby given that at the meeting of the Board of Directors on June 22, 1950, the following addition to Article II, Section 1, of the Bylaws will be voted upon (the new material is in italics):

"Each newly elected Member or Associate Member, and each Junior Member at the time of his transfer into the class of Member or Associate Member, shall pay, immediately upon notification of such election or such transfer, an initiation fee of $20; provided, however, that said initiation fee may be payable, at the option of the applicant, in four equal annual installments, the first of which shall be due upon notification of election or transfer; *and provided further that $1 per year of continuous dues-paying membership either as Student Associate or Junior Member or both, with a maximum of $10, be credited towards the initiation fee of Junior Members transferring to Associate Member or Member.* There shall be no initiation fee for Honorary Members or Junior Members."

What Went on at Recent Local Section Meetings

SECTION	DATE	ATTENDANCE	SPEAKER, AFFILIATION, AND SUBJECT
Ajo Subsection	Mar. 16	19	C. Kettering, Inspiration Cons. Copper Co., on leaching plant.
Alaska	Feb. 27	17	M. Butler, U.S. Engineers, on Perma Frost.
Black Hills	Mar. 17	45	Short talks on the Annual Meeting.
Boston	Mar. 6	175	W. H. Burgers, Technical Univ., Delft, Holland, on growth of metal crystals.
Carlsbad Potash	Mar. 22	55	B. T. Gale, Carlsbad Caverns, on geomorphic history of Carlsbad Caverns area.
Colorado	Mar. 15	52	J. H. East, Jr., and F. T. Allsman, U.S. Bureau of Mines, on the Leadville Drainage Tunnel, its past and future.
Connecticut	Mar. 8	39	J. L. Christie, Handy & Harmon, on silver.
East Texas	Mar. 14	54	F. H. Callaway, Stanolind Oil & Gas Co., on analysis of the effect of well density on recovery efficiency.
El Paso Metals	Mar. 8	52	Joint meeting with Kidd Mining Club. J. C. Rintelin, Texas Western College, on modern trends in metals.
Gulf Coast	Feb. 21	70	L. T. Wehre, United Salt Corp., on the salt industry in Texas.
Gulf Coast	Mar. 21	125	R. J. Gonzalez, Humble Oil & Refining Co., on current trends in the petroleum industry.
Kansas	Feb. 22	50	L. G. Chombart, Schlumberger Well Surveying Corp., on electrical logging in Kansas.
Kansas	Mar. 15	35	P. T. Amstutz, Jr., Amstutz & Yates, on engineering considerations on productivity tests in Kansas.
Montana	Mar. 29	154	F. R. Benedict, Westinghouse Elec. Corp., on the future of power.
Nevada	Mar. 25	70	Dinner honoring Pres. McLaughlin.
New York	Mar. 16	74	C. H. Behre, Jr., Columbia Univ., on geology in relation to Mexican mineral deposits.
North Pacific	Mar. 16	40	K. Cox, Seattle Jr. Chamber of Commerce, on the Hoover Report. L. Heinzinger reported on Annual Meeting.
St. Louis	Feb. 10	64	K. G. Brill, Jr., St. Louis Univ., on coal deposits of Korea.
St. Louis	Mar. 10	76	G. C. Bartholomees, St. Joseph Lead Co., on mining lead in French Morocco.
Southeast	Apr. 4	25	S. L. Hoyt, Battelle Memorial Institute, on metallurgy of welding.
S. California, Mining Branch	Apr. 26		B. F. Darnell, Campo Milling Corp., on new operations of the corporation in San Diego County.
Southwestern New Mexico	Mar. 16	37	P. V. Brough, U.S.S.R. & M., on cyanidation.
Southwest Texas	Mar. 15	188	J. Webber, Atlantic Refining Co., on the fundamental hydraulics in the use of oilwell packers.
Tri-State	Mar. 9	73	E. D. Gardner, U.S.B.M., on development of oil shale mining at Rifle, Colo.
Utah	Mar. 16	71	S. J. Craighead, U.S. Fuel Co., on mechanical coal mining and operating procedure.

Among the Student Associates

On Mar. 8, the Student Chapter of **Texas Western College** and the El Paso Metals Section, AIME, held their annual joint meeting on the campus of Texas Western. Sam Christo, from the Student Chapter, prepared an excellent barbecue dinner which was served in the ore dressing laboratory. After the food was gone, E. M. Thomas, El Paso delegate to the Annual Meeting, gave a report on what went on in New York. Drawing from past experience in the Navy, with International Nickel, and Carnegie Tech., Joseph Rintelin, new addition to the Texas Western faculty, gave a fine talk on modern trends in metals. . . . **University of Southern California** Student Chapter members have elected officers to guide the activities and functions of the chapter for the spring term. Paul F. Newton is President, ably supported by Robert Dill as Vice-President, Donald D. Lloyd as Corresponding Secretary, Lee Freeland as Recording Secretary, and Cliff Dunham as Treasurer. The chapter is fortunate in having both of the previous presidents, A. M. Laurie and Dick Brazier, available for administrative assistance. James G. Jackson has been appointed Journal Secretary for the spring term. . . . Activities of the Mining Engineering Society at **Penn State College** for the spring semester were launched on Feb. 22 with a smoker at the Delta Chi Frat. Students and professor joined in on a bull session. On Mar. 8, new officers were elected: John Todhunter, President; William Davitt, Vice-President; Sam

Sanders, Secretary; and Richard Malloy, Treasurer. During Easter vacation, juniors and seniors in mineral preparation and mining engineering visited mines and plants in Pennsylvania. It's a pleasure to see how well the companies receive the students and plan observation trips. Plans for good meetings for the rest of the semester are well under way. Early last fall the "AIME Big Scoop" was organized, the monthly newsletter of the Penn State chapter. Written and organized by students under the direction of Prof. A. W. Asman, the paper prints news of interest in the Department of Mineral Engineering, announces future meetings and plans, gives news of Penn State graduates, and affords opportunity for students in report writing. . . Recently the **MIT** Metallurgical Society elected officers for 1950-51: Horace N. Lander, President; George A. Bradley, Vice-President; Jerome Hathaway, Treasurer; and Edward E. Hucke, Secretary. The new officers began organizing the chapter's annual chowder party, held with the Boston Section. At this party, **AIME** members get acquainted with student personnel and the activities of the chapter. . . . The Mar. 16 meeting of the Howard Eckfeldt Society of Mining and Geology at **Lehigh University** started off with a short business meeting to discuss plans for a banquet on April 20 and a beer bust on May 12. Jack Graham, of the USGS, in Philadelphia, spoke on ground water; he has spent considerable time on Pennsylvania's water resources. Refreshments finished off the meeting.

COMING EVENTS

MAY

1 Boston Section, AIME.

1 Pittsburgh Section, AIME, Mellon Inst. Auditorium.

1-3 American Geophysical Union, Washington, D. C.

2 Washington, D. C., Section, AIME.

2 Soc. for Applied Spectroscopy, New York.

4 8th Annual Anthracite Conference of Lehigh Univ. and Anthracite Inst., Bethlehem, Pa.

5 Columbia Section, AIME.

6 Chicago Section, AIME, Hotel Shoreland, Chicago, dinner-dance honoring Pres. McLaughlin.

9 Delta Section, AIME.

9 East Texas Section, AIME.

10 El Paso Metals Section, AIME.

10 San Francisco Section, AIME.

12 Oregon Section, AIME.

12 Rio de Janeiro Section, AIME.

15 Detroit Section, AIME.

16 Gulf Coast Section, AIME.

17 Executive & Finance Committees, AIME, New York.

17 Southwestern Texas Section, AIME.

18 Carlsbad Potash Section, AIME.

18 Utah Section, AIME.

23 Montana Section, AIME.

24 Iron & Steel Div., AIME, annual May dinner, Engineers Club, New York.

25 S. California Section, AIME, honoring Pres. McLaughlin

24-25 American Iron and Steel Institute, Waldorf-Astoria Hotel, New York City.

28-31 AIChE, regional meeting, Swampscott, Mass.

28 3d World Petroleum Congress, The Hague, Netherlands.

28 Soc. for Applied Spectroscopy, 5th annual meeting, New York.

29 Alaska Section, AIME.

31 Black Hills Section, AIME, Highland Hotel, Lead, S. Dak., honoring Pres. McLaughlin.

JUNE

2 Columbia Section, AIME.

6-17 Second Mechanical Handling Exhibition and Convention, Olympia, London.

8-10 AIChE, Hotel Statler, Boston.

8-10 National Society of Professional Engineers, Boston, Mass.

9 Rio de Janeiro Section, AIME.

11-15 Amer. Electroplaters' Soc., 37th annual convention, Hotel Statler, Boston, Mass.

12-16 AIEE, Pasadena, Calif.

13 East Texas Section, AIME.

14 El Paso Metals Section, AIME.

15 Carlsbad Potash Section, AIME.

16-17 Central Appalachian Section and Coal Division, AIME, and W. Va. Coal Mining Inst., Daniel Boone Hotel, Charleston, W. Va.

18-20 ASHVE, semi-annual meeting, Royal Muskoka Hotel, Muskoka, Ont.

19-23 American Soc. for Engineering Education, Seattle, Wash.

22 Board of Directors, AIME, New York.

24-30 First international conference on coal preparation under direction of Charbonnage du France.

26-27 Mining Soc. of Nova Scotia, 63d annual meeting, Kentville, N. S.

26-30 ASTM 53rd annual meeting and 9th exhibit of testing apparatus and equipment, Atlantic City, N. J.

JULY

3-7 Gordon Research Conferences, AAAS, on chemistry and physics of metals, New Hampton School, New Hampton, N. H.

3-8 Second Conference on Oil Shale and Cannel Coal, Glasgow.

10-15 World Power Conference, London.

30-31 Mining Association of Montana, Hotel Finlen, Butte.

AUGUST

28-31 American Mining Congress, metal mining convention and exposition, Fair Grounds, Salt Lake City.

SEPTEMBER

5-9 6th National Chemical Exposition, Chicago Coliseum, Chicago.

15-16 National Soc. of Professional Engineers, Wheeling, W. Va.

18-23 3rd International Mechanical Engineering Congress, Brussels.

19-23 Conference on Wire Ropes in Mines, Ashorne Hill, Warwickshire, England.

26-29 Assoc. of Iron and Steel Engineers and Iron and Steel Exposition, Cleveland Public Auditorium, Cleveland.

OCTOBER

4-5 Texas Mid-Continent Oil & Gas Assn., annual meeting, Dallas.

4-6 Petroleum Branch, AIME, New Orleans.

9-13 Washington, D. C., Section & Mineral Economics Division, AIME, joint meeting, Shoreham, Washington.

12-13 Petroleum Branch, AIME, Elks Club, Los Angeles.

13 Southwestern Section, Open Hearth Committee, Iron and Steel Division, Houston, Texas.

20 Eastern Section, Open Hearth Committee, Iron and Steel Division, annual all-day fall meeting, Warwick Hotel, Philadelphia.

23-27 National Metal Congress, Chicago.

23-25 Coal Division, AIME, Fuels Division, ASME, Hotel Statler, Cleveland.

23-25 Institute of Metals Division, AIME, fall meeting, Hotel Sheraton, Chicago.

23-27 ASM, Chicago.

23-27 American Welding Society, Chicago.

23-27 Soc. for Nondestructive Testing, Chicago.

27 Southern Ohio Section, Open Hearth Committee, Iron and Steel Division, annual all-day meeting, Deshler-Wallick Hotel, Columbus.

NOVEMBER

3 Pittsburgh Section, Open Hearth Committee, Iron and Steel Division and Pittsburgh Section, AIME, annual all-day meeting, William Penn Hotel, Pittsburgh.

9 AMC, coal division conference, William Penn Hotel, Pittsburgh.

16-18 GSA, annual meeting, Hotel Statler, Washington, D. C.

DECEMBER

7-9 Electric Furnace Steel Conference, Iron and Steel Division, Hotel William Penn, Pittsburgh.

FEBRUARY 1951

19-22 AIME, annual meeting, Jefferson Hotel, St. Louis.

APRIL 1951

2-4 Open Hearth and Blast Furnace, Coke Ovens and Raw Materials Conference, Iron and Steel Division, Statler Hotel, Cleveland.

The *Drift* of *Things*

as followed by *Edward H. Robie*

Applicants for Membership

To what extent, if any, the names, addresses, biographical records, and endorsers of applicants for membership in the AIME should be published in the monthly journals has long been a matter of controversy. When we joined the Institute, back in 1919, each applicant got an inch or two of space in the journal and all of the above information was included. As the years have gone by, less and less space has been given to this material, so that published data has recently been restricted to the name of the applicant, the town and state where he lives, and a code letter to indicate the grade of membership for which he has applied. Some feel that inasmuch as few read this matter it should be omitted entirely, thus saving the money required to publish it, or enabling the space to be utilized for more acceptable copy. The principal arguments for continuing to publish the names of applicants, in some form, are: (1) occasionally members notice the name of an undesirable candidate and are thus enabled to make a protest before the Board would otherwise accept the applicant; (2) members are thus enabled to see what new members have applied from their local territory; and (3) the applicant himself likes to see his name in print as having applied for membership in his professional society. For these reasons the Council of Section Delegates in February opposed complete omission of the names.

At its meeting on April 21 it seemed likely that the Board would accept a recommendation of the Admissions Committee that hereafter the following procedure be followed. The Branch affiliation of each applicant will be supplied to the respective Editors, who presumably will publish only the names of applicants in the Branch served by their respective journals.

This should make the list of more interest. Members are urged to peruse the names and to report to the Secretary's office if they note any who, they believe, for any reason should not become members, or who are applying for admission as Member when they should properly be Junior Members or Associate Members.

Handling Grievances

Complaints about poor service given members by Institute headquarters have dwindled to a small number but occasionally are still received. Some members feel that even after they have registered a complaint matters are not adjusted to their satisfaction, and they thus have a just grievance.

To handle such cases, the Gillson Committee on Democratization suggested that an individual or a committee be appointed to investigate grievances and see that a satisfactory adjustment is made. The Board referred the suggestion to the Council of Section Delegates, which decided that its own membership should accept this responsibility. Therefore, a member who has a grievance should notify the representative of his own Local Section on the Council, or the Secretary of the Local Section if the Council member's name is unknown to him, and he will see that so far as possible the disgruntled member is satisfied.

The Numbers Racket

In 1949, ME and JM were each marked Vol. 1 because they were the first issues of two new magazines. However, as the Transactions papers therein carried different volume designations, it was decided in 1950 to give the magazine the same volume number as the Transactions volume would have. This will avoid the necessity for dual reference designation—that is, one reference for the magazine and one for the Transactions volume. JPT is, however, continuing with the same volume numbering as used in 1949.

Subsidies and Price Supports

The extent to which the taxpayers of the country are being mulcted to assure profits to various groups of producers in the United States has almost assumed the proportions of a national scandal, and fortunately is receiving increasing attention by our legislators in Washington. A good part of the deficit in our national budget could probably be ended if the Government would stop paying subsidies or buying up products for which there is no market. Likewise the consumer—the public—would be able to purchase these goods for a much more reasonable price.

Most of this Government money goes to agricultural or similar products of the land. Such products are largely the type that, unlike the products of the mineral industry, will deteriorate in storage and thus must be disposed of, usually for little or nothing, or allowed to spoil. In general they must not be disposed of for what they will bring in the market for that would defeat the purpose of the legislation.

On March 1, 1950, the value of the farm crops that the Government had on hand was $4,036,-

175,453 and the Department of Agriculture has requested that two billion dollars more be appropriated to take care of commitments and guarantees the Government has already made. The Government holds more than a billion dollars' worth each of wheat and corn, for instance; almost a billion dollars' worth of cotton; $57,000,000 worth of butter.

Though the situation is anything but funny a rather amusing item appeared in the *New York Herald Tribune* on March 7, which said: "Officials said the department now has about 121,000,000 pounds of dried milk and 72,000,000 pounds of dried eggs. About 1,000,000 pounds of fried eggs have been given away to public welfare groups." They apparently not only give away the eggs but they actually fry them for the beneficiaries, some of whom would probably rather have them scrambled.

Though some in the mining industry have clamored in the past for more Government aid, it is a matter of considerable satisfaction to many that the mining industry is not open to censure in the present sorry mess.

This challenge to the American free enterprise system, and interference with the old law of demand and supply, is also indulged in by many manufacturers who decry the Government's action as to farm commodities. Through the price-fixing laws—euphemistically called "fair-trade" laws—in 45 of our States (but not in Texas, God bless them) a retailer may not cut the price below that set by the manufacturer on a host of articles that he sells. The law is being violated by an increasing number of sellers, and Macy's department store in New York has the matter in the courts. This practice is different of course from Government subsidy and price support, but similar in that the consumer is often forced to pay more than he would in a free market.

Everybody is organized into pressure groups except the consumer.

Coal Still an Industry

Higher prices for coal resulting from the recent strike are said to have led to further inroads by the oil and gas producers on the market for the solid fuel. Some miners are not getting the increased wages they expected because their jobs have evaporated completely. But the coal industry is neither dying nor dead. Witness this extract from the annual report of the Pittsburgh Consolidation Coal Co.: "With all the chaos in the coal industry in 1949 the bituminous mines and the men employed in them produced some 430 million tons, or slightly less than three tons for every inhabitant in the country. This tonnage is about equal to 25% of the combined production of the world and is almost twice the amount of coal produced in any other single country. Oil, gas, and coal combined permit this country to use approximately seven times as much energy per person as is used in the world as a whole. However, price and dependability will determine to a large extent how much of the total energy will be supplied by each of these fuels. In spite of the fact that the productivity of our American miner is from three to six times greater than that of the miners in foreign countries, we must make even greater strides in this regard so that the cost will not bar coal from enjoying its proper share of our increasing national use of energy."

When we consider the enormous resources of the United States, and its immense advantage over all other countries in its use of energy, we are optimistic that Russia will never have the temerity to engage in a war with this country. The only reason why we get so worried sometimes is because we are not sure that our optimism is justified.

Nothing Is Impossible

A young scientific friend of ours, impressed with the marvels of the atomic age, says he is planning an investigation of the behavior of metals in the temperature range just below absolute zero.

Defining the Breed

Sherwin Kelly, himself one of the breed, recently brought back from British Columbia the following definition of a geophysicist, to which he added the words in brackets and submitted the whole for our delectation: A geophysicist is a person who passes as an exacting expert on the basis of being able to turn out with prolific fortitude infinite strings of incomprehensible formulas calculated with micromatic precision from vague assumptions which are based on debatable figures taken from inconclusive experiments carried out with instruments of problematic accuracy by persons of doubtful reliability and questionable mentality for the avowed purpose of annoying and confounding a hopeless chimerical group of fanatics known as geologists, who are themselves the lunatic fringe surrounding the honest and hard working mining engineer, [a bayard who substitutes a powerful dorsal musculature for introspective ratiocination and whose expenditure of herculean efforts is necessitated by his recalcitrant refusal to recognize as meritorious any innovations concerning conservation of muscular or mental travail extraneous to his circumscribed experience or issuing from any but his own terrestrial extractive orifice, and who is obdurately incapable of differentiating a jenny of his proper possession from a speleological phenomenon.]

37 Years Ago

From the Bulletin of the AIME, June 1913: "In view of the great and increasing importance attached to radium and radium deposits, members are urged to communicate to the Secretary any information they may have as to deposits containing radioactive minerals." They still are, only substitute "uranium" for "radium".

Meaning of AIME

AIME means different things to different people. To Mrs. Marie M. Beatty, secretary to the superintendent of the Waukegan Township Secondary Schools, Waukegan, Illinois, who writes enquiring what scholarships we have available, it means "American Institute of Mining and Metallurgical Engravers."

AIME Personals

W. G. Alexander left the Vanadium Corp. of America on Dec. 31, 1948, and worked for a while in Casapalca and later as assistant mine superintendent at Cerro de Pasco in the Yauricocha mine. He left Yauricocha in July 1949 to become manager of operations of the Vanadium Corp. of America in Peru. **Roland McPhee,** who continues as general superintendent, recently spent a vacation in Canada.

Thomas E. Lloyd

Thomas E. Lloyd has been appointed manager of publications of the AIME, succeeding **T. W. Lippert** who resigned recently to accept the position of general manager of the newly-formed Titanium Metals Corp. of America, owned jointly by Allegheny Ludlum Steel Corp. and National Lead Co. For the past 10 years, Mr. Lloyd has held various editorial positions with **The Iron Age** in Detroit, Cleveland, and Pittsburgh, and in 1948 was appointed machinery editor. Prior to joining **The Iron Age,** he had been with the Jones & Laughlin Steel Corp., Pittsburgh.

Maynard F. Ayler, geologist for the California Co., has been transferred to the company's Denver office. His new address is Box 780, Denver 1.

Howland Bancroft has been retained as a consultant to the Cerro de Pasco Copper Corp. and has been elected to the board of directors of the company.

R. H. Bassett has been acting as consulting engineer for the M. A. Hanna Co. since his retirement as chief engineer on Jan. 1.

Bennett R. Bates has moved to Ganges, Salt Spring Island, British Columbia, where he will continue a consulting practice in a limited way.

William R. Cuthbert, chief engineer for the Valley Camp Coal Co. resigned on Mar. 15 to become chief engineer for the West Virginia operations of the Truax-Traer Coal Co., Kayford, W. Va.

Donald M. Davidson, vice-president of the E. J. Longyear Co., is serving on the National Minerals Advisory Council by appointment of the Secretary of Interior.

Madison T. Davis can now be reached at the Holly Mfg. Co., 875 S. Arroyo Parkway, Pasadena, Calif. He had been with the Great Lakes Carbon Corp.

John I. Duffey can be reached in care of the Bethlehem Steel Corp., Caixa Postal, Belem de Para, Brazil.

A. O. Dufresne, deputy minister of the Department of Mines, Quebec, has been elected president of the Canadian Institute of Mining and Metallurgy for 1950-51.

Leon W. Dupuy has been transferred to the new Bureau of Mines regional headquarters at Amarillo, Texas, where he will be in charge of mineral resource work in connection with river basin development.

Charles G. Evensen has moved to Texas to work for the International Boundary and Water Commission. His address is Box 1022, Alpine, Texas.

Clyde N. Garman, who has changed from mill superintendent for Cia. Minera y Agricola Oploca de Bolivia, to superintendent of the sink float plant at Catavi, is now addressed P.M.E.C.I., Catavi, Bolivia.

John F. Haynes left the Braden Copper Co. in Rancagua, Chile, to become mine shift boss at the Santa Barbara unit of the American Smelting and Refining Co. His new address is Cia. Minera Asarco, Santa Barbara, Chih., Mexico.

Parke A. Hodges was recently elected vice-president of Behre Dolbear & Co., consulting mining engineers and geologists of New York. Before joining Behre Dolbear he spent 11 years mining in Chile and Mexico. Returning to the States in 1938 he was mining and chief field engineer for the Climax Molybdenum Co. for 10 years, carrying out examinations of molybdenum, vanadium, tungsten, chrome, and other ferroalloy and base metal deposits in Alaska, the Yukon, Canada, the States, and Mexico. He recently completed a study of the chrome and vanadium deposits of Northern and Southern Rhodesia and a geologic reconnaissance of the mineral possibilities of Southern Rhodesia.

Samuel R. Hoffman is a junior mining geologist with the California Division of Mines. His address is care of Siegel, 195 Alhambra, San Francisco.

Henry F. Hebley

Henry F. Hebley, director of research for the Pittsburgh Coal Co. since 1939, has been appointed consultant to the Pittsburgh Consolidation Coal Co. He will coordinate the company's activities in the control of air and stream pollution, cooperating with both government and civic authorities in these important fields. He is also a representative of the Western Pennsylvania Coal Operators Association working on similar projects. During the late war, he was on the BEW in Australia, conducting studies in oil shale mining. Recently he was a member of a commission sent to Poland and the Ruhr to represent the International Bank for Reconstruction and Development to investigate the rehabilitation of the coal mining industry. His offices are still in the Koppers Bldg., in Pittsburgh.

Daniel E. Huffman a year ago this month took the post of mill superintendent for the New York and Honduras Rosario Mining Co. He and his wife went to San Juancito, Honduras on May 4 and he was stationed at the Main property "Rosario" for three months, traveling to other company properties. On July 15 he was sent over to El Mochito to take charge of the mill.

Primarily it is a silver mine but the ore is highly complex, containing lead, zinc, calcite, and manganese. The metallurgy includes jig, table, flotation, and cyanidation.

E. W. Hunt resigned as superintendent of mines with the Hudson Bay Mining and Smelting Co. to enter the employment of the Newmont Mining Corp. His address for a time is care of Tsumeb Corp., Tsumeb, S. W. Africa.

T. C. Keefer is resident mine manager of the Duport Mine on Cameron Island, Shoal Lake, District of Kenora, Ont. The property is being reopened for a mining examination on behalf of Ventures, Ltd. The work program calls for a surface drilling campaign from the ice of Shoal Lake, to be followed by underground diamond drilling, which will begin as soon as the mining plant has been rehabilitated and the mine workings dewatered. The property has been idle since 1937.

Emil B. Keenan, formerly with the Ford Motor Co., is purchasing officer for the War Department Detroit Arsenal. His mail goes to 19336 Meyers Rd., Detroit 35, Mich.

Frederick F. Kett is retiring after a twenty-year association with the Vanadium Corp. of America, the last twelve years as general manager of the mining division. He will continue to serve as mining consultant to the corporation, with temporary address at 75 Crecienta Drive, Sausalito, Calif.

Desmond F. Kidd, consulting mining geologist of Vancouver, B. C., has been elected chairman of the British Columbia Section of the Canadian Institute of Mining and Metallurgy for 1950. He will also serve the Institute as vice-president for District 6. First and second vice-chairmen are **Harold M. Wright,** consulting metallurgical engineer, and **E. C. Roper,** general manager of the Britannia Mining and Smelting Co., respectively.

A. T. Koenen, former superintendent of the Trout Lake concentrator of the Oliver Iron Mining Co., has been made supervisor of beneficiation.

Kellogg Krebs has opened an office at 564 Market St., San Francisco, as a mineral dressing consultant. For the past 22 years he had been with the American Cyanamid Co.

Henry Krumb has made available to Columbia's School of Mines several scholarships valued at $1000 annually, to be awarded to students interested in mining, metallurgical, and mineral engineering. Mr. Krumb, who has been a member of the AIME since 1905 and was made an honorary member in 1940, is a Columbia graduate.

John F. Magee has been made president of the Alpha Portland Cement Co., Easton, Pa. He had been vice-president.

James E. McDevitt is technical sales manager for the Fly Ash Arrestor Corp., Birmingham, Ala., and New York City. His address is 17 E. 11 St., New York 3.

ing and research in petroleum geology. Dr. Park, who was with the U. S. Geological Survey for fifteen years, is known for his work on the hydrothermal alteration of copper metals, the iron deposits of the Lake Superior district, gold deposits of the Southern Appalachians, and zinc and manganese ores of Washington.

Colorado School of Mines men do well on scholarship winning. John G. Smith, standing, has been awarded the Kennecott Copper Corp. scholarship of $750 for 1949-50 at Mines. Leo Borasio, seated left, and L. R. Wolff, seated right, received the American Smelting and Refining Co. scholarships of $500 each. Louis L. Landers and Roger R. Nelson, not pictured, also received AS&R scholarships. John Smith, a senior in mining engineering, was selected for the Kennecott award on the basis of scholastic record and promise in the mining engineering field. Leo Borasio, mining engineering senior, Lawrence Wolff, Louis Landers, and Roger Nelson, metallurgy seniors, were selected on the basis of scholastic record, personality, and promise of success in the fields of mining and metallurgical engineering.

C. A. McLeish, since graduating from the University of British Columbia last May, has worked as shift boss on a tunnel project and is now superintendent of the Scranton Consolidated Mining Co. His address is Box 517, Kaslo, B. C.

John T. Moran, since graduating from the Missouri School of Mines last July, has been employed as a coal miner at the #7 mine of the Consolidated Coal Co. of St. Louis, Mo. His address is 408 W. First S. St., Carlinville, Ill.

A. E. O'Meara left the engineering staff of the Rimu Gold Dredging Co. in March to go to Mt. Isa, Queensland, Australia, where he has been offered a post as shift metallurgist in the milling department.

Charles F. Park, Jr., has been made dean of the Stanford School of Mineral Sciences, succeeding **A. I. Levorsen,** who will remain on the Stanford faculty as professor of geology, devoting his time to teach-

M. M. O'Brien, managing director of Bralorne Mines, Ltd., has been re-elected president of the British Columbia and Yukon Chamber of Mines. **Harry V. Warren,** of the University of British Columbia, is vice-president. Members of the executive committee include: **Angus Campbell, C. M. Campbell, Horace Fraser,** and **Dale L. Pitt.**

R. Ian Rankin has been appointed to the tunnelling section of the Design and Construction Branch, State Electricity Commission of Victoria at its hydroelectric project on the Krema River in northeastern Victoria. He has been tunnelling superintendent of the No. 4 power station area, Mt. Beauty, Vic.

S. F. Ravitz has left the Salt Lake City station of the Bureau of Mines to join the extractive metallurgy department at the University of California at Berkeley.

Arthur Ward Ruff graduated from the Colorado School of Mines last

May and went to work for Anaconda as a geologist. At present he is a teaching assistant doing graduate work in geology at the University of Arizona, Tucson.

Edmund D. Haigler

Edmund D. Haigler has joined the Fischer & Porter Co. in Hatboro, Pa., to work on special customer engineering problems. Since graduating from Harvard, he has stored up twenty years of experience in industrial instrumentation with the Chevrolet Division of General Motors, E. I. du Pont de Nemours & Co. on ammonia, cellophane, and rayon, and most recently with the Foxboro Co. He managed Foxboro's engineering department for several years, and recently completed a two-year survey of the mining, milling, and smelting industries.

Carmelo T. Sison severed his connection with the Plancoya Engineering and Research Corp. in July 1948 and since then has joined the staff of the Atok-Big Wedge Mining Co. His address is No. 11, Aurora Hill, Baguio, P. I.

Benjamin D. Stewart has retired as territorial commissioner of mines in Alaska after thirty years of service. He went to Alaska in 1910 with the Alaska-Treadwell Gold Mining Co., was appointed mines director in 1919, and in 1935 became commissioner.

James L. Taylor has been appointed construction engineer for the International Minerals & Chemical Corp.; he was chief engineer for the potash mine and refinery of the concern at Carlsbad, N. Mex. His new location is at the central engineering division offices in Chicago.

Harold A. Waite is general manager of Cia. Minera Venturosa, 522 Mills Bldg., El Paso, Texas.

Charles F. Willis, secretary of the Arizona Small Mines Operators Association, Phoenix, has been reappointed a member of the National Minerals Advisory Council.

A. N. Wold retired as chief engineer for the Inter-State Iron Co. last Dec. 31, but will continue with the company in a consulting capacity. He has been with the company since 1918, starting at the Hill-Annex mine at Calumet, eventually becoming chief engineer. He moved to Virginia nine years ago as assistant chief engineer for all company mines. **Howard T. Caddy** has been made chief resident engineer.

Obituaries

Charles Wesley Davis (Member 1936), chief of the metallurgical division, Region III, of the Bureau of Mines, died on Feb. 21, 1950. During his 34-year career with the Bureau Mr. Davis established a reputation for thoroughness in analytical work, pioneered in the development of new metallurgical processes, and demonstrated unusual ability in the advisory, planning, and administrative work of the metallurgical division. Mr. Davis specialized on the separation of radium and uranium at the rare and precious metals stations of the Bureau at Golden and Reno, making his contribution to the analytical work on lead in the investigations of the age of the earth. In 1929 he began work on the metallurgy of iron ores at Pittsburgh, transferring to College Park in 1933, adding to the information on the methods of magnetic measurements and the application of magnetic measurements to the control of steel slag compositions. Mr. Davis continued his work at Rolla and Boulder City, becoming chief of the Boulder City metallurgical branch in 1945.

Robert May Draper (Member 1900) died Feb. 18, 1950, at his home in Belmont, Mass. He was 72 years old. Mr. Draper studied mining and metallurgical engineering at MIT. After graduating he went out to Great Falls, Mont., as chemist for B&MCC&S Mining Co. He worked for Richards & Co., U. S. Smelting Refining and Mining Co., and the Mason Valley Mines Co., before going to Russia in 1930 as a smelter superintendent in Moscow. Two years later he established his residence in Belmont.

Necrology

Date Elected	Name	Date of Death
1943	Tom Lee Ball	June 24, 1949
1934	John B. De Mille	Unknown
1935	Robert L. Klotz	Unknown
1899	Henry M. Lane	Aug. 8, 1945
1914	George D. Nordenholt	May 23, 1949
1915	Thomas C. Peddar	Oct. 27, 1949
1942	Herbert T. Quin	June 14, 1949
1945	P. C. Robbins	Unknown
1916	P. M. Saxman	Feb. 19, 1949
1897	W. W. Taylor	Apr. 27, 1950
1937	Arnulfo Vega	May 15, 1949
1938	Nicholas N. Vishnevsky	Mar. 19, 1950
1927	Richard A. Wagstaff	Mar. 8, 1950
1916	William H. Wasley	Feb. 7, 1950

H. W. Gillett

AN APPRECIATION BY J. G. THOMPSON

H. W. Gillett died from a heart attack on March 3, near Lexington, Ky., on his way home to Columbus after an extended visit to Georgia and Florida.

H. W. Gillett

Horace Wadsworth Gillett was born Dec. 12, 1883 in Steuben County, N. Y. He received an AB from Cornell in 1906 and subsequently worked as a chemist for Thomas A. Edison and for A. D. Little, returning to Cornell in 1908 for his Ph.D. He was manager of the research department of the Aluminum Castings Co., 1910 to 1912; chief alloy chemist of the USBM assigned to the Ithaca, N. Y., station, 1912 to 1924; chief of the metallurgy division of the National Bureau of Standards, 1924 to 1929. Since 1929 he was associated with Battelle Memorial Institute, as its first director from 1929 to 1935, as chief technical advisor from 1935 to his retirement at the end of 1948, and subsequently as consultant.

He became a member of the AIME in 1918 and was Howe Lecturer in 1939. He was Edwin Williams Lecturer for the Institute of British Foundrymen in 1942, and delivered the Second Annual Foundation Lecture of the American Foundrymen's Association in 1944. He received the McFadden Medal of the American Foundrymen's Association in 1932 and was editorial director of "Metals and Alloys", 1929 to 1942. He was a member of the War Metallurgy Committee of the Office of Scientific Research and Development.

His activities covered the entire field of ferrous and nonferrous metallurgy. In his 12 years with the Bureau of Mines, he continued his early work on aluminum and its

FLEXCO® **BELT FASTENERS and RIP PLATES**

FOR HEAVY CONVEYOR AND ELEVATOR BELTS OF ANY WIDTH

Compression Grip distributes strain over whole plate area

★ FLEXCO Fasteners make tight butt joints of great strength and durability.
★ Trough naturally, operate smoothly through take-up pulleys.
★ Distribute strain uniformly.
★ Made of Steel, "Monel," "Everdur." Also "Promal" top plates.
★ FLEXCO Rip Plates are for bridging soft spots and FLEXCO Fasteners for patching or joining clean straight rips.

Order From Your Supply House. Ask for Bulletin F-100

FLEXIBLE STEEL LACING CO.

4629 Lexington Ave., Chicago 44, Ill.

Engineered to move materials with

Speed • Safety • Efficiency

SAUERMAN SCRAPER SYSTEM

DIGS
HAULS
DUMPS IN ONE OPERATION

Above is a Sauerman Scraper System handling a large stockpile of coke at aluminum refinery. Scraper bucket is only 1 cu. yd. capacity yet it stores and reclaims up to 300 tons of coke a day.

A Sauerman Scraper can reach across a pit, pond, bank or stockpile and move material at high speed from one point to another anywhere within its wide radius of operation. These machines are backed by 40 years of experience in designing this type of equipment. Whether it is an installation to handle a hundred tons, or many thousand tons per day, it will be efficient, economical and easily operated by one man.

Send for Catalog on Material Handling

SAUERMAN BROS., INC.

546 S. CLINTON ST. CHICAGO 7, ILL.

alloys, developed the rocking type of indirect arc furnace for melting brass and other metals, and directed the Bureau of Mines World War I investigation of special steels, including uranium steel. This investigation was one of the first to call attention to the merits of molybdenum as an alloying element in steel. At the National Bureau of Standards and subsequently at Battelle, his influence was evident in all of the varied metallurgical activities which he directed.

His ability to assemble and correlate vast quantities of scattered, disconnected facts and data into a compact, clear, and concise whole was a constant wonder to his associates. He was truly a leader, who led by example and never drove anyone but himself. In the laboratory or on his occasional outings for relaxation, if there was ever an unpleasant or disagreeable job to be done his associates usually became aware of the job when they found that it was already under way in Gil's hands.

He will be remembered as a leader in the physical metallurgy of his era, not only for his personal contributions but for his ability to stimulate his associates to better work than even they had recognized that it was possible for them to do.

The **MERRILL-CROWE** *Process*

SIMULTANEOUS PRE-COAT CLARIFICATION
DE-AERATION PRECIPITATION

Recognized as "Standard Practice" in cyanide plants throughout the world.

For information on the Merrill-Crowe Process and equipment, flow diagrams, and helpful data on precipitation, write for your free copy today.

The* MERRILL Company *Engineers

582 Market Street
San Francisco 4, California

IN CANADA
530 King Street, East, Toronto, Ont.

MERCO

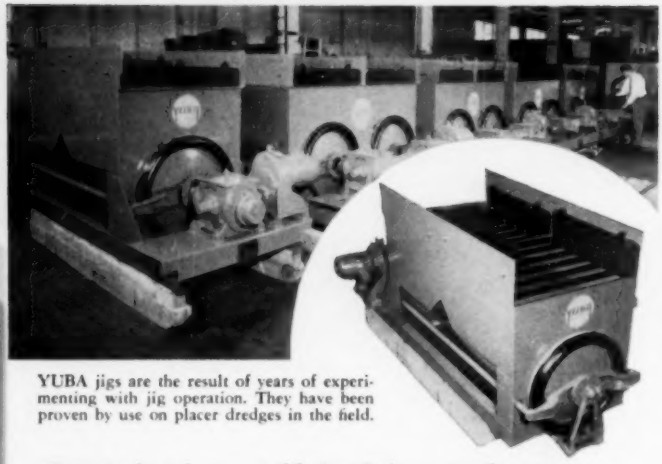
Core Drilling *by Contract*

Exploration for coal and other mineral deposits. Foundation test boring and grout hole drilling for bridges, dams and all heavy structures. ***Core Drill Contractors for more than 60 years.***

JOY MANUFACTURING CO.
Contract Core Drill Division
MICHIGAN CITY • INDIANA

YUBA JIGS INCREASE PLACER RECOVERIES

Designed for placer dredges and other installations; adaptable to all placer dredges.



YUBA jigs are the result of years of experimenting with jig operation. They have been proven by use on placer dredges in the field.

Capture the values . . . gold, tin, platinum, precious stones . . . with YUBA's new placer mining jigs. You trap even the smallest, rusty, or flaky particles that so often float away in older recovery methods. You minimize losses caused by sudden surges of water and sand. YUBA jigs can be easily adapted to your present placer dredge for—

1. Supplementing existing jig equipment
2. Replacing other recovery methods

CHECK THESE SPECIAL FEATURES

YUBA jigs handle coarse feed and quickly capture values because water and jig action can be closely controlled to suit the gravel. They can be supplied singly or in unit multiples of 2, 3, 4, or more cells to suit your volume. Surface action is evenly distributed over the full area of basket. Design holds weight and headroom to a minimum—and most YUBA jig installations require no hull changes. Drives for jig pulsators are completely enclosed and run in oil—operate with little attention. Other YUBA features include:

SPECIAL EQUIPMENT BUILT TO ORDER

Complete steel fabricating, forging, and machine shops at your service. Send us your blue prints or specifications for prices.

- Stainless steel stationary hutch valve
- Simplified stroke adjustment (½" min., 3" max.)
- Maximum frequency—300 at ½" stroke
- Rubber seal between screen grids and basket
- Low power consumption—2 hp. for 4-cell unit
- Stainless steel screens—no rust, constant full openings

Write or wire NOW for data about YUBA's placer jigs and how they can help you to more profitable placer mining.

YUBA DREDGES — PROVEN DEPENDABILITY

YUBA MANUFACTURING CO.

Room 708, 351 California St., San Francisco 4, California, U. S. A.

AGENTS: SIME, DARBY & CO., LTD. · SINGAPORE, KUALA LUMPUR, PENANG.
SHAW DARBY & CO., LTD., 14 & 19 LEADENHALL ST., LONDON, E.C.3.

CABLES: YUBAMAN, San Francisco SHAWDARCO, London

Crispin Oglebay

An Appreciation by V. D. Johnston

Crispin Oglebay (Associate Member 1922), director and executive of several iron ore, coal, shipping, and dock operating companies, died Oct. 23, 1949. Born in Wheeling, W. Va., Oct. 10, 1876, Mr. Oglebay received an A.B. degree from Yale in 1900. In 1903 he became interested in the foundry business in Cleveland, and in 1906 was elected president of the Ferro Machine and Foundry Co., a position which he retained until 1920 when he was elected chairman of the board, continuing in this capacity until 1946.

In 1924 Mr. Oglebay succeeded his uncle, Earl W. Oglebay, as president of Oglebay Norton and Co., a position which he held until he became chairman of the board in 1949. Contemporaneously he became president, vice-president or director of many other companies in allied lines.

As an executive, Mr. Oglebay was democratic, enjoyed simplicity, and was scrupulously honest. He always endeavored to be fair and impartial and was willing and desirous of listening to the ideas and suggestions of others, particularly his associates, invariably resulting in firm and just decisions. He had a keen appreciation of management's responsibility to capital and labor and to the community and government.

He was actively interested and engaged in maintaining a well-rounded cultural and recreational program at Oglebay Park, Wheeling, W. Va., and landscaping and gardening in his residential area at Gates Mills, Ohio. He was also especially interested in tree conservation.

The love of horses which Mr. Oglebay inherited from his father found expression in the breeding and raising of thoroughbred hunters, jumpers and, later, runners. These brought his stables ribbons by the hundreds. One standout was Holystone, son of Man O'War, which won the grand champion in the hunter thoroughbred class in the 1938 National Horse Show. In later years, although a modest stable owner, Mr. Oglebay raced horses in the "big leagues" of the New York and Maryland tracks and his demonstrated knowledge of thoroughbreds earned him the respect of many other thoroughbred fanciers.

Josiah E. Spurr

Just fifty years ago **Josiah Edward Spurr**, who died at his Winter Park, Fla., home on Jan. 12, applied for membership in the AIME and paid the fee for life membership, which was at that time $100. He was then a young geologist, thirty years old, with the U. S. Geological

Survey in Washington. He was born in Gloucester, Mass., Oct. 1, 1870, and stayed in the same state for his education, at Harvard, which granted him an A.B. and A.M. Surprisingly enough, Mr. Spurr, though one of the country's foremost geologists, got by without being a "Doctor".

His first job was with the Minnesota Geological Survey, for which he made the first geological map of the Mesabi Range, then just discovered. He then prepared a bulletin on the deposit and announced his discovery of the origin of the ore in a green iron silicate. His work attracted the attention of S. F. Emmons, who took him on the staff of the USGS. Mr. Spurr then conducted important work in Utah and Colorado, especially at Mercur, Leadville, and Aspen. He conducted the first USGS expedition into interior Alaska and was there when the Klondike was discovered. Subsequent foreign work was in Canada (Mandy mine), in Turkey, and in Nicaragua.

He was a partner with the late J. Rowland Cox in 1908 and following years, and was a "dollar-a-year man" in Washington during the first World War, after which he was chief engineer under the War-Minerals Relief Act. For seven years beginning in 1919 he was editor of E&MJ and made quite a reputation for his scholarly and pungent editorials. He had always been interested in writing, and was the author of many AIME papers as well as several books, of which the most notable were "Geology Applied to Mining" and "The Ore Magmas", which latter aroused a great deal of discussion. He was the leading spirit in founding Economic Geology, and was a president of the Mining and Metallurgical Society. After leaving the E&MJ in 1927 he retired and was rarely seen by his professional friends thereafter, spending his summers at his farm in East Alstead, N. H., and his winters in Florida.

Mr. Spurr was a real scientist, originating many theories of ore deposition. He was also friendly and co-operative with his associates, and the years that the writer spent with him on staff of the E&MJ were most pleasant and stimulating ones.—*E.H.R.*

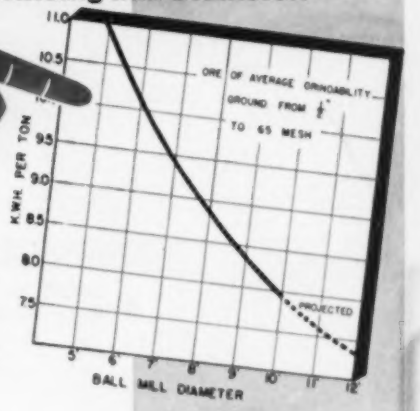
Tasker Lowndes Oddie (Member 1902), one of Nevada's most successful governors and for two terms U. S. senator, a man who played an important part in Nevada mining development during the Tonopah boom days, died in San Francisco Feb. 17 at the age of 79. Senator Oddie, Brooklyn born, was admitted to the New York Bar in 1895 and to the Nevada Bar in 1896. He was Jim Butler's close legal and financial advisor in the pioneering days when a large portion of the mining world flocked to Tonopah and later to Goldfield and was a well known figure in the camps. He was elected governor in 1910 and initiated reforms that proved highly beneficial to the state. He began his two terms as U. S. senator in 1921 and served on numerous influential committees. After leaving the Senate, he emphasized his belief in Nevada's mining possibilities by going out to look for another fortune in the gold and silver districts.

Thomas Clifford Peddar (Member 1915), owner and publisher of South Pacific Mail, died Oct. 27, 1949, after a long illness. By the time he was 18 he had left England, where he was born and educated, and took up prospecting and surveying in southern Chile. He worked for Antony Gibbs & Co., prospecting, surveying, and managing mines. He then became manager of Cia. Minas de Cobre de Gatico, later continuing his association with Gibbs & Co. Mr. Peddar was a director of Cia. Cuprifera de Sagasca and Cia. Rafaelitas del Neuquen.

Arnulfo Vega (Member 1937), manager of Cia. Minera Idria, Concheño, Chih., Mexico, died May 15, 1949. Mr. Vega was born at Meogui, Chih., in 1916, but went to El Paso when a child, and earned his metallurgy degree at Texas Western. He went to work for Minas de Pinos Altos as a millman, eventually becoming mill superintendent. When that company was liquidated in 1946 he went to Concheño to supervise the installation of the new flotation mill of Cia. Minera Idria. He was subsequently named gen-

HERE'S PROOF...

Power Consumption Varies With Grinding Mill Diameter!



To show you what happens to power costs with a change in mill diameter, here are data averaged from actual reports from commercial operators over a period of years. Note that power consumption per ton of feed is roughly in inverse proportion to mill diameter. **You cannot compare mills of different diameter on the basis of equal power.**

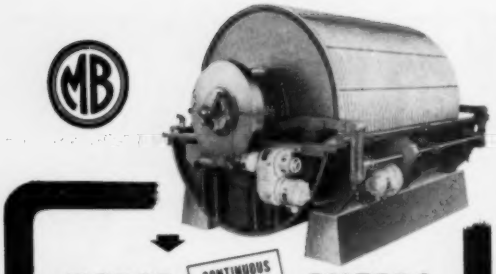
Size for size, MARCY low pulp line ball and rod mills have been proved to have greater capacity than grinding mills of any other type, with corresponding savings in power per ton of finished product and generally better metallurgical results. Ask our engineers to analyze your grinding problems without cost or obligation to you.

OTHER PRODUCTS

Mosseo Fahrenwald Flotation Machines; Genuine Wilfley Tables; Mosseo-McCarthy Hot Millers; Buck Bi Grinders; Duality Controllers; Belt Feeders; Pinch Valves; Assay and Laboratory Supplies and Equipment; Complete Milling Plants; Centrum Ski Lifts.

THE Mine & Smelter SUPPLY COMPANY

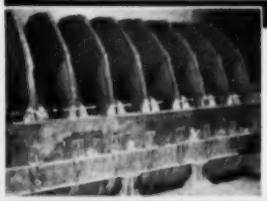
Main Office: DENVER, COLO., U.S.A.
El Paso, Salt Lake City, 1775 Broadway, New York, N.Y.
Representatives: Canadian Vickers, Ltd., Montreal; W. R. Judson, Santiago and Lima; The Edward J. Nell Co., Manila, P. I.; The Ore & Chemical Co., 30 Broad St., New York 4, N.Y. for Continental Europe



MORSE CONTINUOUS VACUUM FILTERS

PARAMOUNT IN EFFICIENCY AND MECHANICAL DEPENDABILITY

Dependable for Continuous Duty—Fully Automatic. Morse Drum and Disc Filters are highly regarded for satisfactory performance and low maintenance—made in a wide range of sizes to meet most all requirements.



MORSE DISC FILTERS

are ideal for filtering more than one character of concentrate or material where separate filtrates are desired.

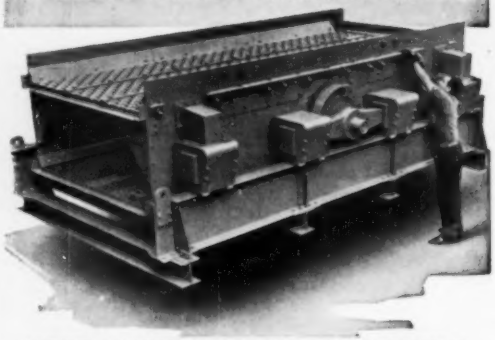
Write for Bulletin No. 4710

MORSE BROS. MACHINERY COMPANY

ESTABLISHED 1899

DENVER, COLORADO, U. S. A. (CABLE MORSE)

TY-ROCK—the Ideal Screen for HEAVY LOADS—COARSE MATERIALS!



USED THROUGHOUT THE WORLD WHEREVER LARGE TONNAGES OF ROCK OR ORE ARE SCREENED!

Manufacturers of Woven Wire Screens and Screening Machinery

THE W. S. TYLER COMPANY

CLEVELAND 14, OHIO • U. S. A.

eral superintendent and finally manager.

Frederick W. C. Whyte (Member 1900), formerly general manager of the coal departments of the Anaconda Copper, died Sept. 14, 1949. Mr. Whyte was born in Scotland in 1863, served his apprenticeship and held his first jobs in Glasgow. He came to the States in 1887 and did engineering work in New Mexico and Montana and was chief engineer on the Butte Anaconda & Pacific Railway during construction. In 1895 he joined the coal department of Anaconda, becoming general manager two years later.

William Arthur Wasley (Member 1916), concentrator superintendent for the Cananea Consolidated Copper Co., Cananea, Sonora, Mexico, died on Feb. 7. He was 64 years old. A native of Platteville, Colo., he graduated from the Colorado School of Mines in 1909. Then was the beginning of the "porphyry coppers" and like many other young engineers he sought actual experience in his chosen profession, that of metallurgical engineer. He was employed first at the concentrator of the Utah Copper Co. He also worked for AS&R at Garfield and for Miami Copper, soon to be advanced to representative of this company at Cananea as the copper concentrates from Miami were being sent there for smelting. This was the beginning of his long career in Mexico, for in 1912 he went to work for the Lucky Tiger Mining Co., remaining there 12 years. He then was with the Fresnillo Co., the Mexican Candelaria Co., and Cia. Minera Santa Maria de Oro. He went to Cananea in 1944 as superintendent of the 12,000 ton concentrator then nearing completion. His long experience in Mexico was of invaluable aid in the organization of the staff and the selection of the men for the operations of this plant. I well remember that he said in one of his letters to me prior to his coming to Cananea, "You will not find me lazy." The correctness of this statement was borne out in our association of the succeeding years. Bill had a wonderful disposition and his even temper stood him in good stead, not only with his immediate associates and superiors, but likewise with the workmen among whom he had a host of friends. We all mourn his passing. —*Guy H. Ruggles.*

Proposed for Membership

Total AIME membership on Mar. 31, 1950, was 16,397; in addition 4037 Student Associates were enrolled.

ADMISSIONS COMMITTEE

E. C. Meagher, Chairman; Albert J. Phillips, Vice-Chairman; George B. Cortess, Lloyd C. Gibson, Ivan A. Given, P. Malozemoff, Richard D. Mollison, and John Sherman.

Institute members are urged to review this list as soon as the issue is received and immediately to write the Secretary's Office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privileges to every person to whom it can be of service but does not desire to admit persons unless they are qualified.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; AM, Associate Member; S, Student Associate.

Arizona

Ajo—Young, Joe Bay. (C/S—S-J).
Clarkdale—O'Brien, Richard Clarke. (C/S—S-M).
Ray—Barkley, James Robert. (C/S—S-J). Williams, Robert I. (C/S—S-J).
Safford—Tomkinson, Joe Alfred. (M).
Superior—Pillar, Charles Littlefield. (R, C/S—J-M).

California

Bakersfield—Davis, Chester Arthur. (C/S—J-M). Marshall, Warren Monroe, III. (J).
Glendale—Parker, Richard Lee. (C/S—S-J).
Huntington Park—Farrow, John Robert. (J).
Los Gatos—Frye, Everett Stanton. (C/S—AM-M).

Los Angeles—Barr, Gordon William. (R—M). Fernandes, Robert John. (C/S—S-J). Sampson, Norman Nathan. (C/S—J-M).
McKittrick—Campbell, Harry Duncan. (C/S—AM-M).
Monterey Park—Barber, Delmont Davis. (M).
Ontario—Greene, William Ambrose. (C/S—S-J).
Pasadena—Cerf, Charles Joseph. (M).
Richmond—Pratt, William Held. (C/S—J-M).
San Francisco—Reno, Robert Evans, Jr. (M)

Colorado

Climax—Walker, Marvin Stanley. (R, C/S—J-M).
Colorado Springs — Magruder, James Alexander. (AM).
Denver—Newton, Douglas Edmund. (C/S—S-M).
Pueblo—Gabelman, John Warren. (C/S—S-J).
Uravan—Clark, Henry D. (M). George, Jack Wesley. (R, C/S—J-M). Tschanz, Charles McFarland. (C/S—S-J). Van Fleet, Thomas Ricard. (R, C/S—S-J).

Connecticut

Darien—Griffin, Frank Alexander. (M).
Fairfield—Marston, William Thomas. (M).
New Canaan—Marshall, Carl Alexander. (M).
Southington—Francis, Leonard William. (R, C/S—S-AM).
Stamford—Hartjens, Hermen. (C/S—J-M).

Delaware

Wilmington—Desy, Donald Herbert. (C/S—S-J).

Florida

Lakeland—Linder, Paul Scott. (J).

Illinois

Chicago—Clark, Horace Herbert. (R—M). Rumfelt, Henry F. C. (M). Senior, Franklin Cumming. (M).
DePue—Wyman, George Francis. (M).
LaGrange—Burrack, Harry Bob. (M).
Maywood—Koebel, Norbert Kenneth. (M).
Park Forest—Hall, Lewis Dana. (J).
West Frankfort—Karlovsky, Jerry, Jr. (C/S—S-J).

Indiana

Hammond—Bradley, Robert Calvin. (C/S—S-J).
Terre Haute—Lentz, Jerome Victor. (AM).

Kansas

Eureka—Campbell, William Henry. (J).

Kentucky

Ashland—Miller, Robert Jackson. (M). Todd, George Hensel. (M).

Louisiana

Monroe—Ford, Elbert Estelle. (M).

Maryland

Silver Spring—Spendlove, Max Jones. (AM).

Michigan

East Lansing—Sweet, Robert Louis. (C/S—AM-M).
Houghton—Goodyear, Frank Taylor Crim. (C/S—S-J).

Minnesota

Crosby—Stetson, Harland John. (C/S—S-J).

Mississippi

Laurel—Hamilton, Walter Frederick. (C/S—J-M).

Missouri

Joplin—Austin, Arthur Bradford. (AM).

For instance...

If you are faced with sticky concentrate drying problems, the Ruggles-Coles Class "XH" Dryer is the answer. This dryer was developed by Hardinge especially for the drying of concentrates—particularly flotation concentrates. Gone completely are the old problems of sticking or "balling" in the dryer. An ingenious baffle and lifting flight arrangement overcomes this. Write for Bulletin 16-D-2; state pertinent details of your drying problem.

HARDINGE
COMPANY INCORPORATED
YORK, PENNSYLVANIA — 240 Arch St. • Main Office and Works
NEW YORK 17—122 E. 42nd St. • 205 W. Wacker Drive—CHICAGO
SAN FRANCISCO 11—24 California St. • 200 Bay St.—TORONTO

Montana

Mike Horse—Augustson, Anders Everet. (C/S—S-J).

Nevada

Boulder City—Baker, Don H., Jr. (C/S—S-J).
Ruth—Brown, Arnold Lee. (C/S—S-J).

New Jersey

Chatham—Pfann, William Gardner. (C/S—J-M).
East Paterson — Franklin, Frederick Francis. (M).
Hohokus—Burrows, Henry Peter. (AM).
Westfield—Mayne, Charles Russell. (M).
West Orange—Driver, Robert Orrell. (M).

New Mexico

Carlsbad—Clark, Harold P. (R, C/S—S-M).
Silver City—Davis, Richard R. (AM).

New York

Bronxville—Pels, Alan Robert. (J).
Forest Hills—Speaker, Francis Braun. (C/S—AM-M).
Katonah—Davis, Donald Wilfred. (C/S—J-M).
Newton Falls—Ross, Alexander, Murray. (M).
New York—Piana, Louis D. (C/S—S-J).
Troy—Deshpande, Raghunath Chintaman. (C/S—S-J).

Ohio

Ashtabula—Yake, William Harry. (C/S—S-J).
Bellaire—Jordan, Luis, Jr. (C/S—J-M).
Blacklick—Newton, William Harding. (R-M).
Cincinnati—Kahles, John Frank. (C/S—J-M). McConnell, William Cameron. (M).
Cleveland—Bradley, Morris Alva. (AM). Robards, Chester Frazier. (R, C/S—S-M). Zorko, Frank Anton Valentine. (C/S—S-J).
Lakewood—Morrison, Donald M. (C/S—AM-M).
Youngstown—Gayton, Oscar Francis. (M).

Oklahoma

Bartlesville—Tarner, Jack. (C/S—J-M).
Duncan—Pendley, Dee Finas, Jr. (J).
Enid—Duff, Thomas H. (C/S—S-J).
Norman—Porter, Alfred Watson, Jr. (J).
Oklahoma City—Durham, Elbert Norvin. (R, C/S—J-M). Hill, Freeman Lee. (C/S—S-J).
Tulsa—Elliston, Henry Harold. (M). Johnson, Douglas Ostrom. (R—M). Knotts, Max Leon. (C/S—S-J). Muratta, Robert Wyman. (AM). Stafford, Joseph Dewey, Jr. (J). Willson, Charles Otis. (M).

Oregon

Corvallis—Robberson, Ronald Frank. (C/S—S-J).
Portland—Cappa, Francis Xavier. (C/S—J-M).

Pennsylvania

Bridgeville—Marquis, Bernard Ernst. (M).
Carbondale—Colville, Kenneth Hendrick, Jr. (J). Dann, Benjamin George, Jr. (J).
Easton—Miltenberger, Robert Stanley. (J).
Finleyville—Blair, James Philip. (J).
Hazleton—Mitchell, Donald Leroy. (AM).
Lansford—Turrall, William Thomas. (M).
Mount Carmel—Rothrock, Howard Eugene. (M).
Nanticoke—Jones, Donald William. (M).
Palmerton — Taylor, Charles Edward. (M.)
Philadelphia—Rassbach, Herman Philip. (M).
Pittsburgh—Bauman, Arthur Harvey. (C/S—S-J). Fulton, Paul Franklin. (C/S—J-M). Gorman, Henry Benjamin. (J).

Shaw, James Marshall. (J). Wyllie, Malcolm Robert Jesse. (M).
State College—Mullen, Willard F. (M).

South Dakota

Estelline—Burge, Furman H., Jr. (C/S—S-J).

Texas

Beaumont—Cokinos, Geneos Pete. (R, C/S—S-M).
Bellaire—Kent, William Dexter. (R, C/S—J-M). Morris, Wesley Dixon. (C/S—J-M). Sherwin, Mel William. (M).
Brownfield—Ray, Jack Harris. (C/S—S-J).
Corpus Christi—Wallace, Robert Roy. (C/S—S-J).
Dallas—Monkhouse, George Sedberry. (C/S—J-M).
El Paso—Foester, Hallard Lewis. (AM).
Gladewater—Ziomke, Charles Donald. (J).
Hawkins—Kempe, Gerald Lloyd. (J).
Hebbronville—Thomas, Henry Evans. (J).
Houston—Blouin, Cecil Francis. (M). Cain, Lester Lee. (J). Cook, Winfield Hollis. (M). Floeter, John Sydney. (R, C/S—S-M). Nice, Frank Allen, Jr. (M). Wright, Randolph Earle. (J).
Midland—Brown, Billie Joe. (J). Brown, Jack Weldon. (J). Clark, Joe Richard. (J). Gillett, Dan. (J). Guenther, Richard Stewart, Jr. (C/S—S-J). Keeler, William Arnold. (J). Landtiser, Paul Keith. (J). Tompson, Gilbert Carr. (J). Trott, James Irby. (R, C/S—S-J).
Odessa—Ousterhout, Raymond Sherburn. (M).
Pleasanton—Kirby, John Elmer, Jr. (R, C/S—S-J).
Scroggins—Grolemund, John Lafayette. (J).
Seagraves—Hutchins, Charles H. (C/S—J-M).
Texas City—Naylor, Roger A. (J).
Wink—Purdy, Eugene William. (J).

Utah

Orem—Hinds, Gene Wesley. (C/S—S-J).
Salt Lake City—Hodgins, H. B. (M).
Spring Canyon—Pauley, Clarence Everett. (M).

Vermont

South Strafford—Joyce, Joseph William. (C/S—S-J).

Washington

Everett—Irvine, Gordon Benjamin, Jr. (C/S—S-J).
Spokane—Taber, John William. (C/S—J-M).

West Virginia

Beckley—Wilson, Crawford Lindsay. (M).
Huntington—Smith, Herman Eugene. (J).
Montcoal—Kane, Chester Opal. (M).

Wisconsin

Marinette — Lindlof, Raymond George. (C/S—S-AM).
Shullsburg—Lasio, John. (R, C/S—S-M).

Wyoming

Riverton — Johnston, Myron Thomas. (M).
Thermopolis — Allen, Thomas Newton. (M).

Alaska

Anchorage—Harlan, Garth Byron. (C/S—S-M). Robinson, Wiley David. (M).

British Columbia

North Vancouver — Heffernan, Gerald Robert. (M).

Ontario

Welland—Preston, Thomas B. (C/S—S-J).

Quebec

Abitibi—Dumont, Georges H. (M).

Appraisals
Assayers
Chemists
Construction
Consulting
Designing

Professional Services

Space limited to AIME members or to companies that have at least one member on their staffs. One inch, $40 per year; half inch, $25 payable in advance.

C. CANNING BARNARD
Mining and Geological Consultant
East and Central Africa and the Rhodesias
P. O. Box 705, Nairobi, Kenya Colony. Tel.: 5319

JAMES A. BARR
Consulting Engineer
Specializing in Non-Metallics
505 Halong Ave. Mt. Pleasant, Tennessee

BLANDFORD C. BURGESS
Registered Professional Engineer
Mining Consultant
Monticello, Georgia

GLENVILLE A. COLLINS
Mining Engineer
Uranium examinations Cable "Colas"
210 La Arcada Bldg. Santa Barbara, Calif.

COWIN & CO.
Mining Engineers and Contractors
Consulting Shaft & Slope Sinking
Appraisal Mine Development
Reports Mine Plant Construction
930 2nd Ave., No., B'ham, Ala. Phone 3-4271

HUBERT O. DE BECK
Consulting Geological Engineer
CERAMIC RAW MATERIALS and INDUSTRIAL MINERALS
P. O. Box 823 3108 Speedway
Custer, South Dakota Austin 21, Texas

BEHRE DOLBEAR & COMPANY
Consulting Mining Engineers and Geologists
11 Broadway New York 4, N. Y.

EDWIN S. GILES
Consulting Mining Engineer
In Goldfield since 1905
GOLDFIELD NEVADA

CARLTON D. HULIN
Mining Geology
26th Floor San Francisco 4
Shell Building California

LEDOUX & CO. INC.
Assayers Chemists
Shippers representatives at all seaports and refineries in the United States
155 Sixth Ave. New York

T. E. LLOYD
Sintering Consultant
Room 3700 70 Pine St.
Wh. 4-2200 New York 5, N. Y.

MARK C. MALAMPHY & CO. LTD.
Consulting Geologists and Geophysicists
P. O. Box 209, Mufulira, Northern Rhodesia
Experienced field crews available for examinations and surveys anywhere in Africa.

JOSEPH T. MATSON
CONSULTING MINING ENGINEER
Examinations—Appraisals—Operations
P. O. Box 170 Santa Fe, New Mexico

CLAYTON T. McNEIL, E. M.
Mine Examination, Reports, Supervision, Operation
822 Bank of America Bldg. Tel. GArfield 1-2948
SAN FRANCISCO 4, CALIFORNIA

ARNOLD H. MILLER
Consulting Engineer
Mine, Mill and Industrial Investigations
Improvement Design and Recommendations
Cable: "ALMIL" Tel. Cortlandt 7-0835
120 Broadway New York 5, N. Y.

RODGERS PEALE
Consulting Mining Geologist
315 Montgomery St.
San Francisco 4, Calif.

ROGER V. PIERCE
Mining Engineer Specialist
Underground Mining Methods, Cost Cutting Surveys—Production Analysis—Mine Mechanization—Mine Management
1566 Wasatch Drive Salt Lake City 4, Utah

LUCIUS PITKIN, INC.
Mineralogists
Assayers—Chemists—Spectroscopists
Shippers' Representatives
PITKIN BLDG., 47 FULTON ST., NEW YORK
Cable Address: Niktip

MILNOR ROBERTS *Consulting Mining Engineer*
The Pacific Northwest, British Columbia and Alaska
4501 12th Ave., N.E. Seattle, Wash.

CLOYD M. SMITH *Mining Engineer*
Ventilation Surveys
Operational Reports Appraisals
Munsey Building Washington 4, D. C.

SEWELL THOMAS
Consulting Mining Engineer
Plant Layout, Design, Detailing, Mechanization, Mining Methods
380 GILPIN STREET DENVER 3, COLO.

WM. HUFF WAGNER
Mining Engineer and Geologist
Examinations, Reports and Appraisals
631 Tower Building Washington, D. C.

LELAND A. WALKER
Consulting Mining Engineer
Management, Mining Methods, Examinations
146 So. West Temple St. Salt Lake City 1, Utah

O. W. WALVOORD CO.
Mill-Design and Construction
401 High St. Denver 3, Colo.

WALKER & WHYTE, INC.
Assayers, Chemists
Shippers' Representatives
400 Pearl St. (Corner New Chambers)
New York U.S.A.

HARRY J. WOLF
Mining and Consulting Engineer
Examinations—Valuations—Management
420 Madison Avenue, New York 17, N. Y.
Cable: MINEWOLF Tel.: PLaza 9-1700

ALLEN & GARCIA COMPANY
38 Years' Service to the Coal and Salt Industries as Consultants, Constructing Engineers and Managers.
Authoritative Reports and Appraisals
332 S. MICHIGAN AVE., CHICAGO
120 WALL ST., NEW YORK CITY

B. B. R. DRILLING CO.
Scenery Hill Martins Ferry, O.
Diamond Core Drilling Contractors
Mineral Foundation
Cores Guaranteed Testing

BOOTH ENGINEERS
LIONEL E. BOOTH, MANAGER
Consultants in Metallurgy • Ore Testing Plant Operation • Process and Equipment Development
146 SOUTH WEST TEMPLE STREET
SALT LAKE CITY 1, UTAH

Drilling
Geophysicists
Management
Metallurgical
Reports
Valuations

DIAMOND DRILLING IN MEXICO
New Equipment
Experienced Drillers
THEODORE A. DODGE
215 Av. Obrego N., Nogales, Sonora, Mex.
201 North Court St., Tucson, Arizona

EAVENSON & AUCHMUTY MINING ENGINEERS
Mine Operation Consultants
Coal Property Valuations
2720 Koppers Bldg. Pittsburgh 19, Pa.

MILTON H. FIES
Consulting Engineer
Rooms 1201-2
Alabama Power Co. Bldg.
Birmingham, Alabama

CHESTER A. FULTON
Consulting Mining Engineer
10 East 40 St. New York City 16
MUrray Hill 9-1530
302 Somerset Rd. Baltimore 10, Md.
Belmont 1353

T. W. GUY
Consulting Engineer
Coal Preparation
TO YIELD MAXIMUM NET RETURN
FACE AND PRODUCT STUDIES
PLANT DESIGN AND OPERATION
Kanawha V. Bldg. Charleston, W. Va.

ABBOT A. HANKS, Inc.
ASSAYERS-CHEMISTS
Shippers Representatives
624 Sacramento Street
SAN FRANCISCO

JOSEPH R. LINNEY
Consultant
MINES • MILLS • METALLURGY
30 Years' Experience Adirondack Magnetites
38 Clinton St. Plattsburg, N. Y.

E. J. LONGYEAR COMPANY
Foshay Tower Minneapolis, Minn.
Consulting Mining Engineers and Geologists
Mineral Exploration — Mine Valuation

DIAMOND CORE DRILLING CONTRACTORS
Testing Mineral Deposits
Foundation Borings
MOTT CORE DRILLING CO.
Huntington, W. Va.

PENNSYLVANIA DRILLING COMPANY
PITTSBURGH 20, PA.
DRILLING CONTRACTORS and MANUFACTURERS
We prospect coal and mineral land anywhere in North and South America.
Core borings for foundation testing; dams, bridges, buildings, etc.

PIERCE MANAGEMENT, INC.
MINING ENGINEERS
A Background of 22 Years of Design, Consulting, and Management Service to Coal and Mineral Industries in 28 States and 18 Foreign Countries.
Scranton Electric Bldg. 1025 Connecticut Ave., N.W.
Scranton 3, Pa. Washington 6, D.C.

PAUL F. SCHOLLA
Consulting Mining Engineering
Metal & Industrial Mineral Mining
Examination — Management
Development — Surface Plants
Foreign and Domestic
1025 Connecticut Avenue, N.W.
WASHINGTON 6, D. C.

SPRAGUE & HENWOOD, Inc.
SCRANTON 2, PA.
Diamond Drill Contractors and Manufacturers
Core borings for testing mineral deposits in any part of the world.

UNDERPINNING & FOUNDATION COMPANY, INC.
155 EAST 44TH STREET
NEW YORK 17, N. Y.
Specialists in Design and Construction of Shafts and Tunnels

S. POWER (PI) WARREN, EM.MSc.
MINERAL AND METAL BENEFICIATION PROBLEMS
Only those commitments desired which include personal, on the job attention
1910 Kalorama Rd., N.W. North 5442
WASHINGTON 9, D. C.

W. T. WARREN
V.P., MacLEAN DEVELOPMENT CORP.
Mining Engineer—Consultant
1. EXAMINATIONS & GENERAL ANALYSIS
2. UNDERGROUND OPERATING PROBLEMS
a) Safety c) Secondary Blasting
b) Low-cost Stoping d) Production
MacLean Development Corporation
Route 1, Box 440 Reno, Nevada

JOEL H. WATKINS
Mining Geologist
INDUSTRIAL MINERALS
CHARLOTTE C. H. VIRGINIA

J. W. WOOMER & ASSOCIATES
Consulting Mining Engineers
Modern Mining Systems and Designs
Foreign and Domestic Mining Reports
Union Trust Bldg., Pittsburgh, Pa.
National Bank Building, Wheeling, W. Va.

L. E. YOUNG
Consulting Engineer
Mine Mechanization — Mine Management
Oliver Building Pittsburgh, Pa.

Cuba

Habana—Fisher, Arnold Joseph. (M).

Trinidad

San Fernando—Holte, Justin LeRoy. (C/S—S-J).

Argentina

Jujuy—Guerrico, Martin. (J).

Brazil

Sao Paulo—Correa Da Silva, Luiz Coelho. (C/S—S-J).

Chile

Chuquicamata — Cadwell, Graham Matthews. (M).

Ecuador

Guayaquil—Avery, Don. (C/S—S-J).

Venezuela

Caracas—Sykes, Harry John. (C/S—J-M).

France

Meuse—Arnould, Andre Marcel. (M).
Paris—Armanet, Jean Charles. (R—M).

Gold Coast Colony

Tarkwa—McMillan, Alexander Marshall. (M).

India

Jaipur City—Sethi, Munshi Lal. (C/S—S-J).
Madras — Narasimhan, Asthagiri Subbaiyer. (J).

Japan

Kagawaken—Yamagath, Shiro. (M).

New South Wales

Sydney — Hamilton, Frank Alexander. (C/S—J-AM). Richardson, Gilbert Robert. (C/S—J-M).

New Zealand

Wanganui — Billinghurst, William McMinn. (C/S—S-J).

Iron and Steel vs. Abrasive Minerals

- Write now for 32 page reprint on "Wear Tests."
- Reprints of an informative and authoritative paper (published by the American Institute of Mining and Metallurgical Engineers), giving the statistical results of extensive wear tests on a wide range of grinding ball materials, are now available.
- "Abrasion Factors" for materials of different compositions and treatment have been developed from the results of these tests. These factors can be applied to many other abrasive conditions.
- This is information not yet available in book form. Write for your copy now!

Climax Molybdenum Company
500 Fifth Avenue New York City

MAIL THIS COUPON

Please send me a FREE copy of 32 pp reprint on WEAR TESTS

Name.....
Company.....
Address.....

MOLY

MIE. 5 FIG

Advertisers' Index

NEW PUBLISHING SCHEDULE

SPACE RESERVATION	—	1st	PRECEDING MONTH
PLATES IN NEW YORK	—	7th	" "
MAGAZINE ISSUED	—	23rd	" "

Aero Service Corp. ..... *
The Aitkin-Kynett Co.

Allen-Sherman-Hoff Co. ..... Third Cover
Eugene A. Holland

Allis-Chalmers Mfg. Co. 532, 538, 545
Compton Advertising, Inc.

American Cyanamid Co. ..... *
James J. McMahon, Inc.

American Manganese Steel Div., American Brake Shoe Co. 533
Fuller & Smith & Ross, Inc.

Anaconda Copper Mining Co. 536
Kenyon & Eckhardt, Inc.

Clarkson Mfg. Co. ..... *
Eggers-Rankin Adv. Service

Climax Molybdenum Co. 638
Rowlinson-Broughton

Colorado Fuel & Iron Corp., Wickwire Spencer Steel Div. 546a
Fuller & Smith & Ross, Inc.

Colorado Iron Works Co. ..... *
The Shaw-Schump Adv. Agency, Inc.

Deister Concentrator Co. ..... *
Louis B. Wade, Inc.

Denver Equipment Co. ..... *

Dorr Co., The ..... *

Dow Chemical Co., The Great Western Div. ..... *
MacManus, John & Adams, Inc.

Eimco Corp., The 537
Matrie Co.

Euclid Road Machinery Co. ..... *
The Bayless-Kerr Co.

Flexible Steel Lacing Co. 631
Kreicker & Meloan, Inc.

Gardner-Denver Co. 539
The Buchen Co.

General Electric Co. ..... *
G. M. Basford Co.

Goodman Mfg. Co. .....
L. H. Gross and Assoc.

Hardinge Co., Inc. 635
The W. H. Long Co.

Harnischfeger Corp. ..... *
The Buchen Co.

Hendrick Mfg. Co. ..... *
G. M. Basford Co.

Hercules Powder Co., Inc. ..... *
Fuller & Smith & Ross, Inc.

Hercules Powder Co. (Flotation) 548
Fuller & Smith & Ross, Inc.

Ingersoll-Rand Co. 534
Richard & Co.

International Nickel Co., Inc. 546b
Marschalk & Pratt Co.

Jones & Laughlin Steel Corp. ..... *
Ketchum, MacLeod & Grove, Inc.

Joy Mfg. Co. 631
Walker & Downing

Link-Belt Co. 543
Don Proctor Adv.

Longyear Co., E. J. ..... *

Merrill Co. 631
The McCarty Co.

Mine & Smelter Supply Co. 633
The Shaw-Schump Adv. Agency, Inc.

Mine Safety Appliances Co. ..... Fourth Cover
Walker & Downing

Morse Bros. Machinery Co. 634

National Technical Laboratories ..... *
Dozier-Graham-Eastman

Nordberg Mfg. Co. ..... *
Russell T. Gray, Inc.

Radiac Co., The ..... *
Admiral Adv.

Sauerman Bros., Inc. 631
Symonds, MacKenzie & Co.

Sheffield Steel Co. ..... *
R. J. Potts-Calkins & Holden Adv.

Stearns Magnetic Mfg. Co. ..... *
Eldred Vetter Agency

Texas Gulf Sulphur Co. ..... *
Sanger-Funnell, Inc.

Traylor Engineering & Mfg. Co. 541
Kamp and Godfrey, Inc.

Tyler Co., W. S. 634

Webster Industries, Inc. 540
George A. Mellor

Wellman Engineering Co. ..... *
The Griswold-Eshelman Co.

Western Machinery Co. 535
Walther-Boland Assoc.

Wheel Truing Tool Co. ..... *
Clark & Rickerd, Inc.

Wilfley & Sons, Inc., A. R. ..... Second Cover
Ed M. Hunter & Co.

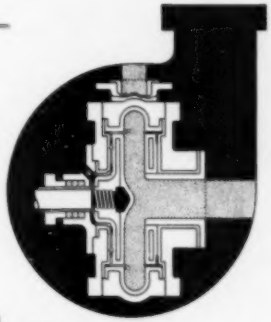
Wilmot Engineering Co. ..... *
Wilbur A. Myers

Yuba Mfg. Co. 632
George C. McNutt Adv.

* Previous Issues

IN MOVING ABRASIVE SOLUTIONS

make your MTS. into mole hills



HYDROSEALING

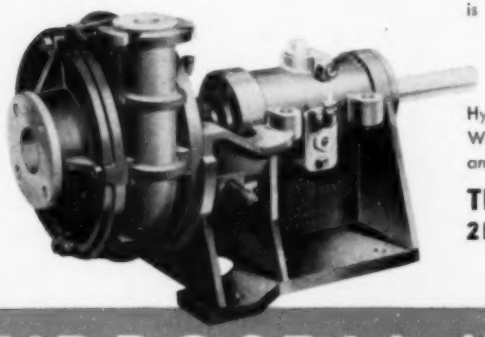
keeps abrasive-laden water out from between the pump's impeller and side-plates —a big factor in the efficiency and economy with which you can pump abrasives anywhere and under any condition in your plant.

Maximix Rubber PROTECTION

Abrasives bounce off Maximix Rubber parts, to which flexibility gives 4 to 6 times the useful life of equivalent parts made of metal.

Continued ENGINEERING

A pumping system with Hydroseal is not only tailor-made for your specific needs, but is followed-up systematically as to performance. This practice assures continued efficiency, and is a basis for our authoritative planning.



When you write for more information on Hydroseals, tell us about your pumping problem in detail. We'll gladly suggest the system that will do your job best and also save you money.

THE ALLEN-SHERMAN-HOFF CO.
213 S. 15th Street • Philadelphia 2, Pa.
Representatives in Most Principal Cities

HYDROSEAL

SAND, SLURRY & DREDGE PUMPS
MAXIMIX RUBBER PROTECTED

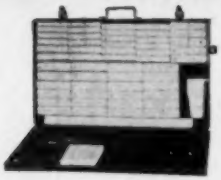
HYDROSEAL, PACKLESS AND MAXIMIX DESIGNS ARE COVERED BY PATENTS AND APPLICATIONS IN THE MAJOR MINING CENTERS OF THE WORLD

In the training and practice of **BETTER FIRST AID**

MSA
SAFETY EQUIPMENT HEADQUARTERS

. . . and for First Aid Training THE M·S·A CONTEST OUTFIT

A complete unit of equipment for first aid training and contests, this outfit provides the complete list of materials recommended by the U. S. Bureau of Mines for first aid practice and contest work, contained in a strong steel box which is easily transported. The box, which is finished in white, is made of 24-gauge steel, and is equipped with a strong handle at each end. The M. S. A. Contest Outfit aids neatness and efficiency, prevents loss of materials. Write for details!



M·S·A MINERS FIRST AID CABINET

This completely-equipped cabinet contains a large assortment of first aid materials and supplies meeting the needs of mine hospitals or dressing stations. The contents conform to materials recommended by the United States Bureau of Mines for first aid treatment. The sturdy steel case is designed for wall mounting, or transportation when required. Bulletin FA-74.

M·S·A ALL-WEATHER FIRST AID KITS

Providing dependable protection against dust, dirt and moisture for assortments of unit-packaged first aid materials, M. S. A. All-Weather First Aid Kits feature strong steel cases with replaceable rubber gasket which seals edges tightly when kits are closed. The unit packages contain one or more treatments for single injuries, without waste. Kits are available in 10-, 16-, 24-, and 36-unit sizes. Bulletin FA-101.

M·S·A REDI-HEAT BLOCK

Using replaceable Redi-Heat charges, this unit provides quick, safe emergency heat for first aid applications. Always ready for immediate use, the M. S. A. Redi-Heat Block employs no liquids. The charges are unaffected by external conditions and have unlimited storage life. Bulletin FA-92.

MINE SAFETY APPLIANCES COMPANY

BRADDOCK, THOMAS AND MEADE STREETS . . . . . PITTSBURGH 8, PA.

At Your Service: **48 BRANCH OFFICES in the UNITED STATES**

MINE SAFETY APPLIANCES CO. OF CANADA LIMITED · Toronto, Montreal, Calgary, Winnipeg, Vancouver, New Glasgow, N.S.
MINE SAFETY APPLIANCES CO. (S.A.) (PTY.) LTD. · Johannesburg, South Africa; N'Dola, No. Rhodesia; Bulawayo, So. Rhodesia

Representatives in Principal Cities in Mexico, Central and South America CABLE ADDRESS: "MINSAF" PITTSBURGH